TM 55-1067

WAR DEPARTMENT TECHNICAL MANUAL

ENGINE, MARINE, DIESEL

GENERAL MOTORS,

MODEL 12-278A

Note. This is a reprint of TM 55-1067, Maintenance Manual for Model 12-278A General Motors Diesel Engines, 27 September 1943. No distribution will be made to personnel possessing the original publication.

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WAR DEPARTMENT • 27 SEPTEMBER 1943

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TM 55-1067, Engine, Marine, Diesel, General Motors, Model 12-278A, is published for the information and guidance of all concerned.

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BY ORDER OF THE SECRETARY OF WAR:

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The Adjutant General

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This book has been specifically prepared to cover the General Motors Model 12-278A Diesel Engines with engine serial numbers 15193 to 15222 inclusive, manufactured under War Department, U. S. Army Transportation Corps Contract W2789 tc 1225.

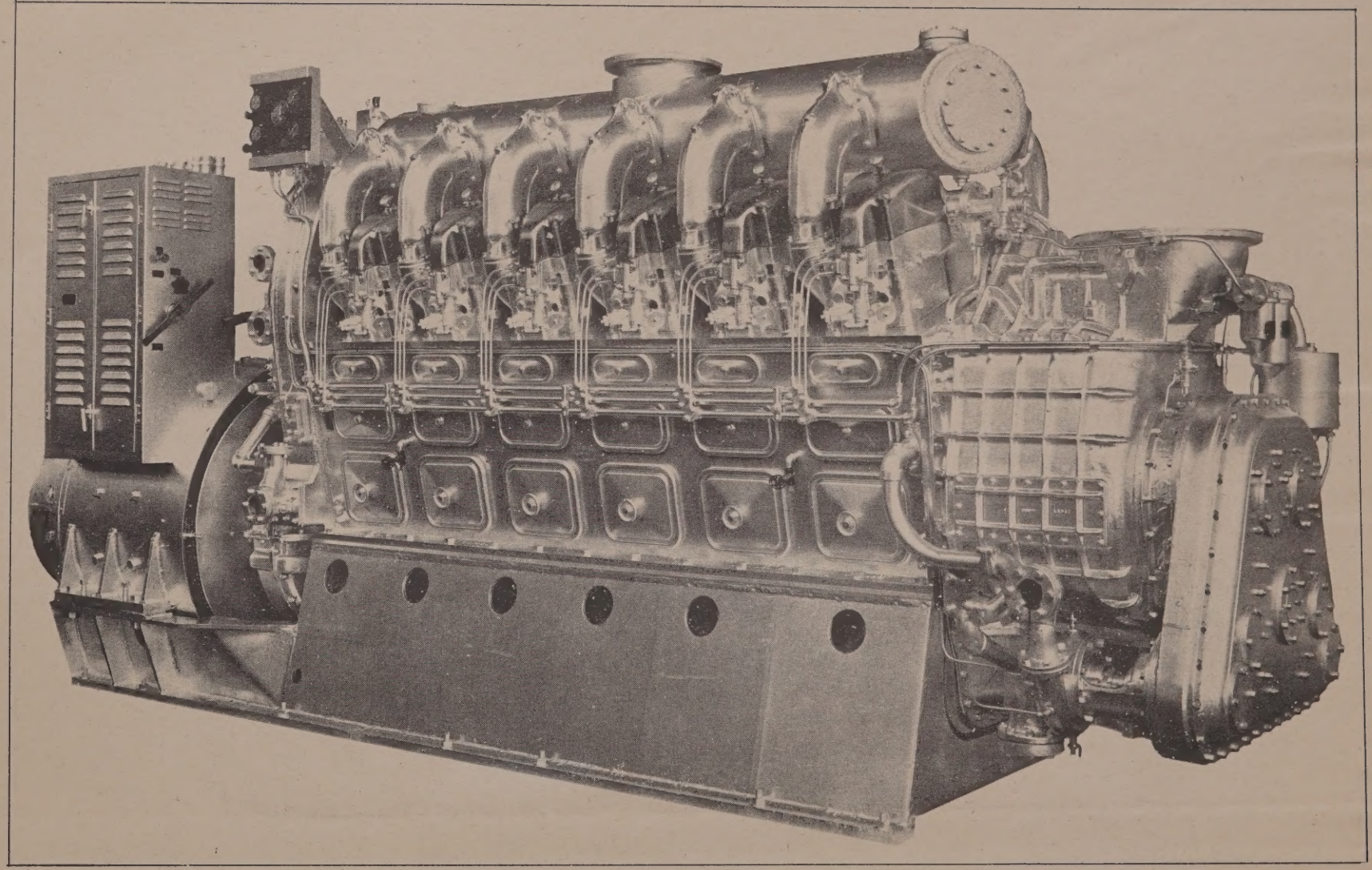


Fig. 1A
Blower End and Side of Engine

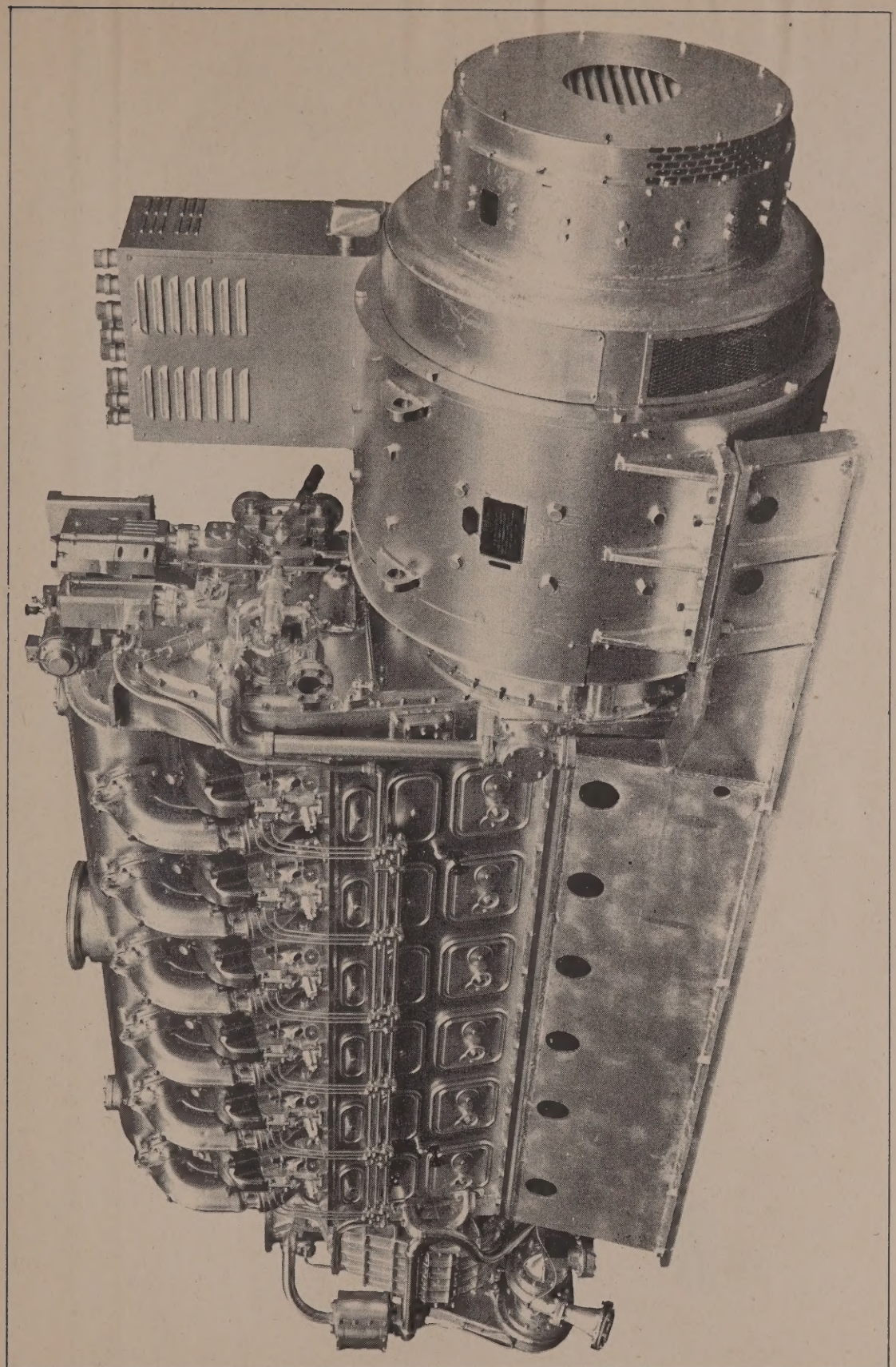


Fig. 2A
Generator End and Side of Engine

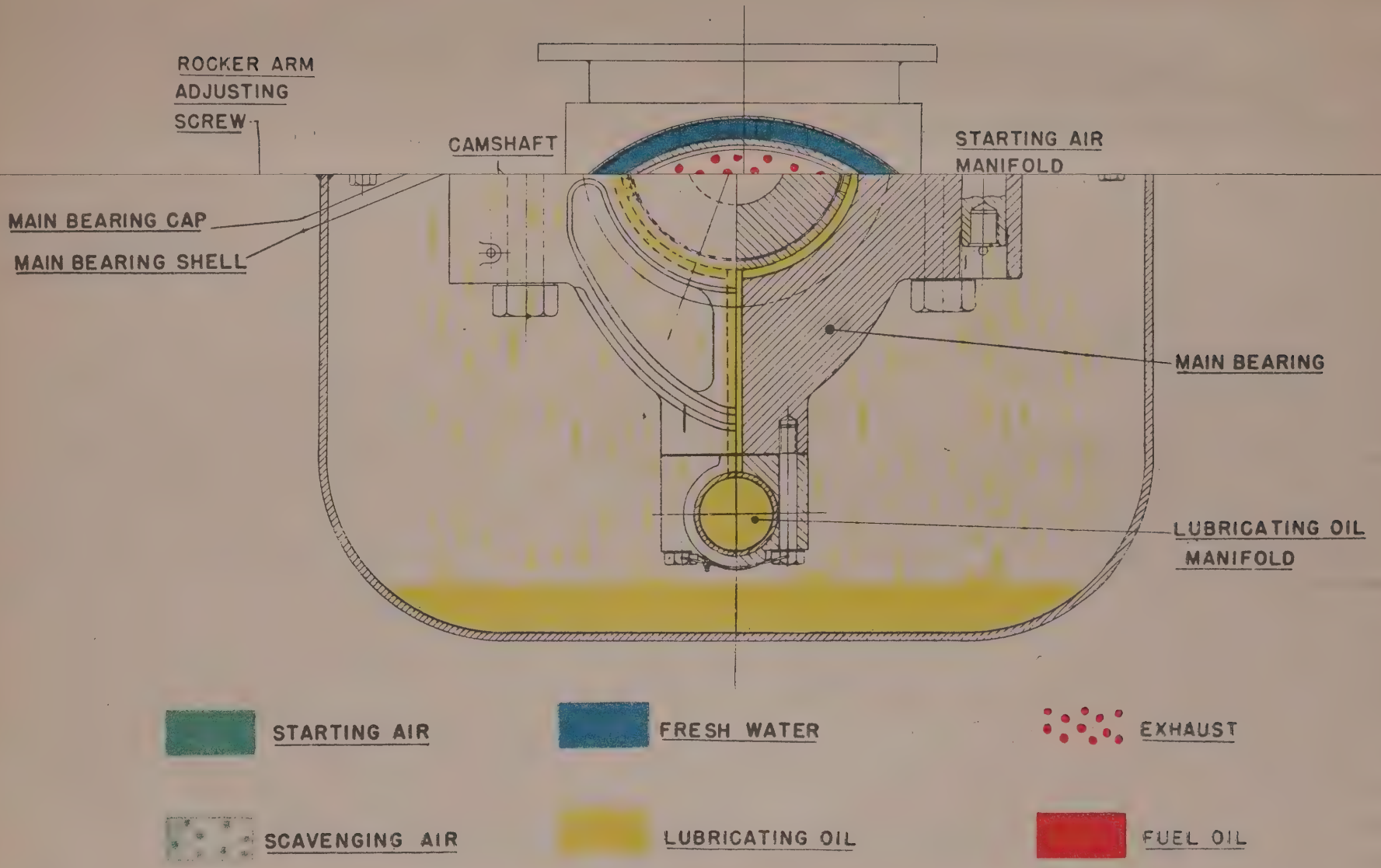


Fig. 3A

Fig. 3A
Model 278 Engine Cross Section Showing Lubricating Oil, Fuel Oil, Water, and Air

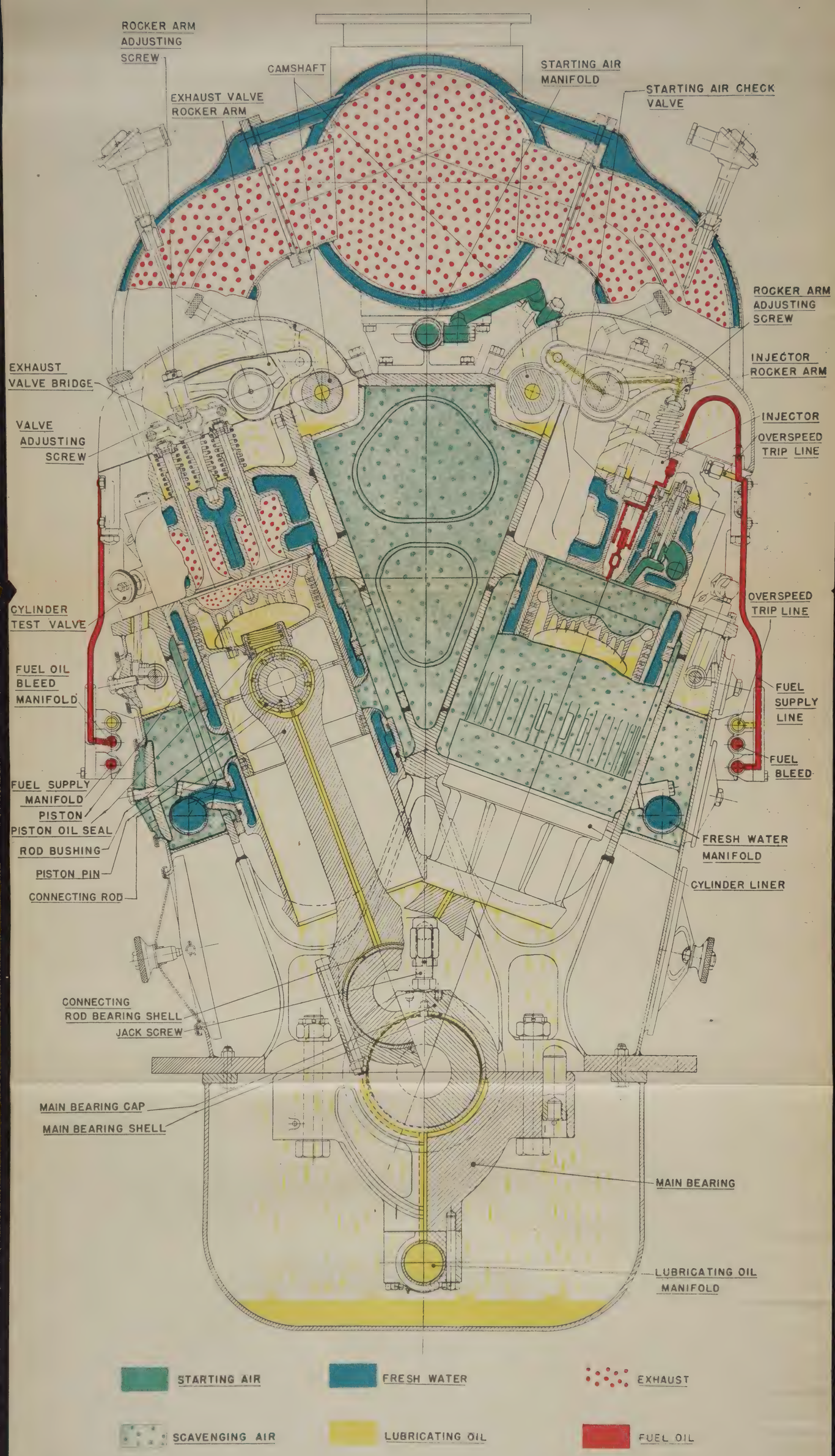


Fig. 3A

Fig. 3A
Model 278 Engine Cross Section Showing Lubricating Oil, Fuel Oil, Water, and Air

THE TWO CYCLE DIESEL ENGINE

The Diesel Principle. The diesel engine is an internal combustion engine. Internal combustion engines convert the heat of fuel into work in the cylinder of the engine tiself.

The diesel engine differs from the gasoline engine principally in the method used to introduce and ignite the fuel. The gasoline engine draws a mixture of fuel and air through the carburetor into the combustion chamber, where it is ignited by an electric spark. In the diesel engine, air alone is compressed in the cylinder, then a charge of fuel is sprayed into the cylinder after the air has been compressed, and ignition is accomplished by the heat of compression.

The Two Cycle Diesel Engine. Two strokes are required to complete a cycle in the two cycle engine. The intake and exhaust take place during part of the compression and power strokes, so an external means of supplying the air must be provided. A specially designed blower, bolted to the front of the engine, forces air into the cylinders in order to expel the exhaust gases and fill the cylinders with fresh air for combustion, as shown in Figs. 1B, 2B, 3B and 4B.

A series of ports cut into the circumference of the cylinder liner wall above the piston, in its lowest position, admit the air from the blower into the cylinder as soon as the top of the piston uncovers the ports, as shown in Fig. 1B. The flow of air through the ports toward the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air.

As the piston continues on the upward stroke, the exhaust valves close, the piston covers the inlet ports, and the charge of fresh air is subjected to the final compression, as shown in Fig. 2B.

Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the

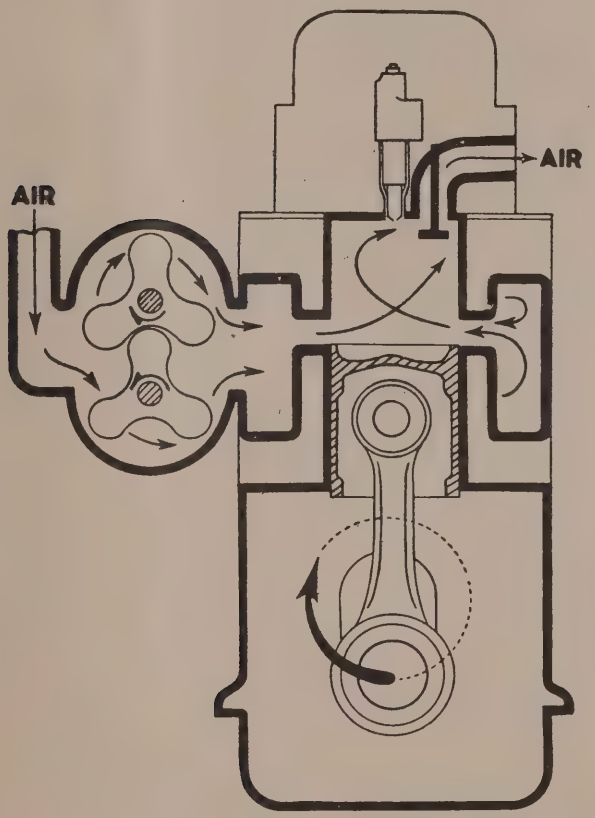


Fig. 1B

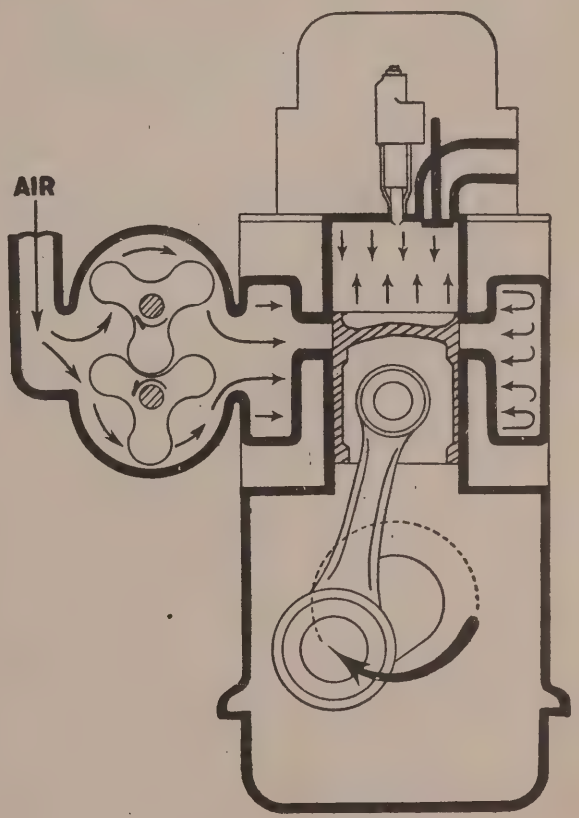


Fig. 2B

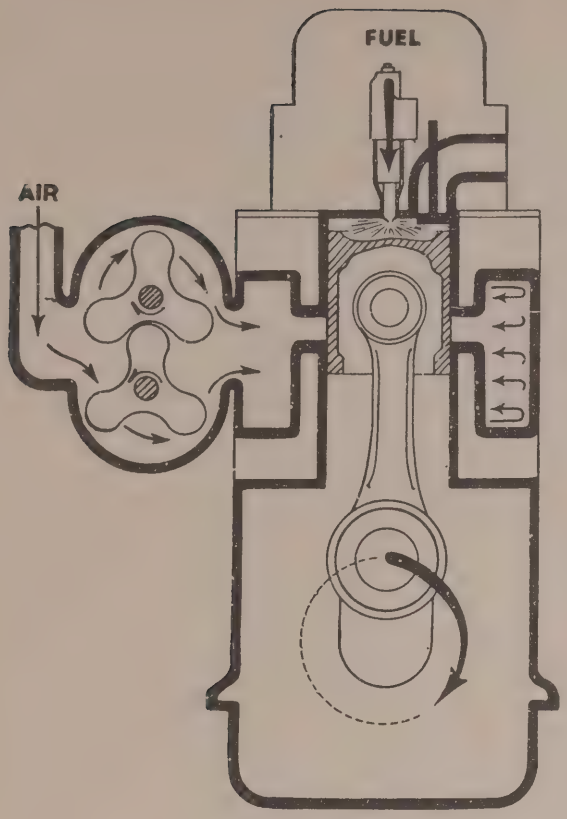


Fig. 3B

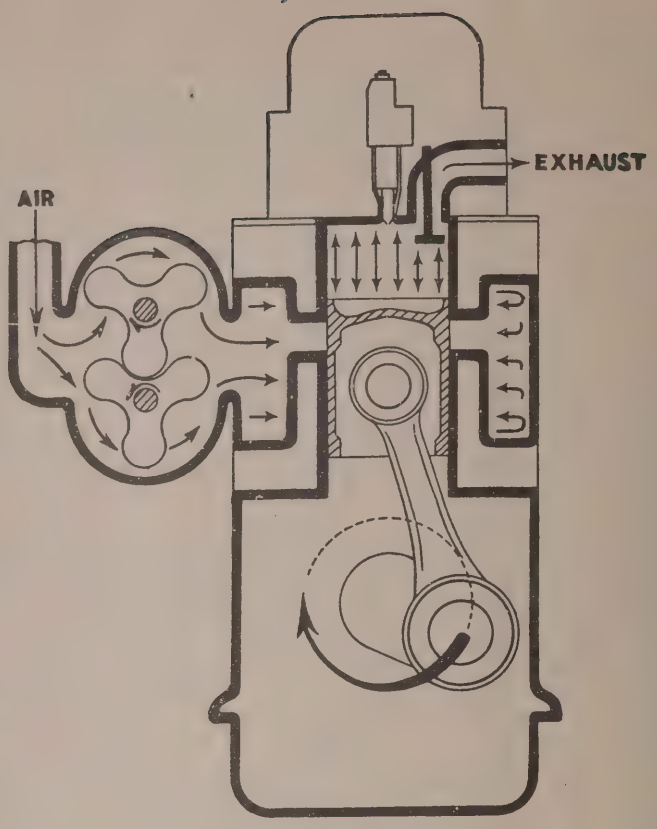


Fig. 4B

combustion space by the unit fuel injector, as shown in Fig. 3B. The intense heat generated during the high compression of the air ignites the fine fuel spray immediately, and the combustion continues as long as the fuel spray lasts. The resulting pressure due to the expansion of the gases during combustion forces the piston downward until the exhaust valves are again opened. As shown in Fig. 4B, the burnt gases escape into the exhaust manifold and the downward moving piston is about to uncover the inlet ports. When these ports are uncovered, the cylinder volume is again swept with clean scavenging air, as shown in Fig. 1B. This entire combustion cycle is completed in each cylinder for each revolution of the crankshaft, or, in other words, two strokes of the piston, hence, the "two-stroke cycle."

DATA, RATINGS AND CLEARANCES

Engine Data

Model Number	12-278A
B.H.P.	950
Generator Output	605 kw.
Rated Engine Speed	750 r.p.m.
B.M.E.P.	66.2 lbs. per sq. in.
Type of Engine	2 cycle
Type of Cylinder Arrangement	"V" type
Number of Cylinders	12
Bore and Stroke	8¾ x 10½
Firing Order—L. H. Rotation	1-7-6-12-2-8-4-10-3-9-5-11
Starting System	Starting winding in generator

Recommended Operating Data

Pressures at Full Load and Speed	*Lbs. per sq. in.*
Lubricating Oil Pressure into Engine (from Cooler)	40-50
Fuel Oil Supply Pressure to Injectors	40-50
Sea Water Pressure at Pump Discharge (to Coolers)	19-35
Fresh Water Pressure at Pump Discharge (to Engine)	24-37
Pressure Drop of Fresh Water through Clean Lubricating Oil and Fresh Water Coolers Both Together (Approx.)	10
Pressure Drop of Sea Water through Clean Water Cooler (Approx.)	4
Pressure Drop of Lubricating Oil through Clean Lubricating Oil Cooler (Approx.)	10

Temperatures at Full Load and Speed	*Deg. F.*
Average Exhaust Temperature (with Exh. Back Press. of 1" Hg. or 13.6" H_2O)	400-500
Lubricating Oil Temperature from Engine	Min. 140—Preferred 165—Max. 180
Lubricating Oil Temperature from Cooler	120-160
Fresh Water Temperature to Water Cooler (from Engine)	140
Fresh Water Temperature from Water Cooler (to Lubricating Oil Cooler)	110-130
Sea Water Temperature at Pump (to Cooler)	85 Max.
Temperature Rise of Sea Water through Fresh Water Cooler	10-20

Pressure Relief Valve Setting	*Lbs. per sq. in.*
Lubricating Oil Pressure Regulating Valve at Full Load and Speed	40-50
Lubricating Oil Pressure Regulating Valve at 375 r.p.m. and No Load	8-12
Lubricating Oil Pressure Relief Valve—at Engine Inlet	50
Lubricating Oil Pressure Safety Relief Valve (at Scavenging Pump)	90
Fuel Oil Bleed Line Pressure Relief Valve (Pressure to Injectors)	40-50
Fuel Pump Discharge Safety Valve	60-65
Lub. Oil Cooler By-pass Valve (Lub. Oil Press. Drop Through Cooler) (Furnished by Shipbuilder)	30

Miscellaneous	
Exhaust Valve Stem Cap Clearance	.015"
Overspeed Gov.—Engine Speed at Release	825-862 r.p.m.

Torque Limits for Bolts and Studs	*Ft. Lbs.*
Cylinder Head Studs	650
Connecting Rod Bolts	100
Main Bearing Bolts	550
Cylinder Liner Studs	175

Blower and Attached Pump Data

750 r.p.m. Engine Speed

Blower

Type	Positive Displacement
Blower Speed	1650 r.p.m.
Engine Charging Pressure with Exh. Back Pressure of 1″ Hg. or 13.6″ H_2O	5.5″ Hg.
Free Air Deilvery	4380 cu. ft. per min.

Cooling Water Pumps

Manufactured by	Ingersoll-Rand Co., Phillipsburg, New Jersey
Location of Pump	On blower end of engine
Type	Centrifugal pump

Sea Water Pump:

Pump Speed	2310 r.p.m.
Capacity	325 g.p.m.

Fresh Water Pump:

Pump Speed	2310 r.p.m.
Capacity	300 g.p.m.

Lubricating Oil Pumps

Type	Positive displacement
Location of Pumps	On camshaft drive housing

Pressure Pump:

Manufactured by Cleveland Diesel Engine Division General Motors Corp., Cleveland

Pump Speed	1318 r.p.m.
Capacity	75 g.p.m.

Scavenging Pump:

Manufactured by Cleveland Diesel Engine Division General Motors Corp., Cleveland

Pump Speed	1318 r.p.m.
Capacity	75 g.p.m.

Fuel Oil Pump

Type	Positive displacement
Manufactured by	Viking Pump Co., Cedar Falls, Iowa
Location of Pump	Blower end of camshaft
Pump Speed	750 r.p.m.
Capacity	3.13 g.p.m.

Engine Oil and Water Capacities

Fresh Water System (Attached)	42 gal.
Lubricating Oil System (Attached)	15 gal.

Clearances

The clearances shown are manufacturing clearances to be used only in the installation of new parts. These clearances are not to be used as wear limits or as an indication of when parts are to be renewed. For wear limits on specific parts see instructions in the body of the book.

	Size	*Clearance*
Cylinder liner bore	8.7495″ to 8.7505″	
Piston diameters:		
Top of taper, at top of head	8.695″ to 8.697″	0.0525″ to 0.0555″
Bottom of taper, top of 5th ring groove	8.720″ to 8.722″	0.0275″ to 0.0305″
Skirt from 5th ring groove to bottom end	8.732″ to 8.734″	0.0155″ to 0.0185″
Piston rings—clearance between groove sides:		
Top two compression rings		0.0080″ to 0.0105″
Next three compression rings		0.0040″ to 0.0065″
Oil rings		0.0020″ to 0.0045″
Piston rings—gap width, wings compressed to 8¾″ diameters:		
All rings		0.030″ to 0.050″
Piston top below cylinder head—crank at top dead center:		
Normal clearance		0.068″
Minimum and maximum clearance—		
Total effect of manufacturing limits		0.066″ to 0.089″
Piston pin bearing diameters:		
Bushings in piston	3.0005″ to 3.0015″	
Piston pin	3.000″ to 2.999″	0.0005″ to 0.0025″
Piston pin bushings, inside diameter	3.0025″ to 3.0035″	
Piston pin	3.0000″ to 2.9990″	0.0025″ to 0.0045″
Connecting rod boss	3.8760″ to 3.9765″	
Piston pin bushing, outside diameter	3.8730″ to 3.8720″	0.0030″ to 0.0045″
Crankpin diameters:		
Bearing shell	6.256″ to 6.257″	
Crankpin	6.2495″ to 6.2485″	0.0065″ to 0.0085″
Main bearing diameters:		
Bearing shell	7.2555″ to 7.2575″	
Crankshaft journal	7.2495″ to 7.2485″	0.006″ to 0.009″
Main thrust bearing lengths:		
Crankshaft journal	5.000″ to 5.002″	
Bearing shell	4.968″ to 4.970″	0.030″ to 0.034″
Camshaft bearing diameters:		
Bushing	2.2556″ to 2.2540″	
Journal	2.2505″ to 2.2495″	0.0035″ to 0.0061″
Camshaft drive—backlash—all gears		0.006″ to 0.008″
Camshaft drive gear:		
Bushing	5.377″ to 5.378″	
Journal	5.372″ to 5.370″	0.005″ to 0.008″
Lubricating oil pump drive gears:		
Bushing	3.000″ to 3.001″	
Journal	2.997″ to 2.996″	0.003″ to 0.005″

	Size	*Clearance*
Camshaft and crankshaft idler gears:		
Bushing	3.000″ to 3.001″	
Journal	2.997″ to 2.996″	0.003″ to 0.005″
Blower and pump drive—backlash—all gears		0.006″ to 0.008″
Accessory drive gear—bearing diameters:		
Bushing	3.502″ to 3.503″	
Journal	3.499″ to 3.498″	0.003″ to 0.005″
Water pump idler gears:		
Bushing	2.251″ to 2.252″	
Journal	2.249″ to 2.248″	0.002″ to 0.004″
Water pump gears:		
Bushing	2.251″ to 2.252″	
Journal	2.249″ to 2.248″	0.002″ to 0.004″
Blower gear bearing diameters:		
Blower drive gear:		
Bushing	3.252″ to 3.253″	
Journal	3.249″ to 3.248″	0.003″ to 0.005″
Blower rotor gears:		
Bushing	3.7510″ to 3.7520″	
Journal	3.7480″ to 3.7475″	0.0030″ to 0.0045″
Blower rotor bearing diameters—rear:		
Bushing	3.7510″ to 3.7520″	
Journal	3.7480″ to 3.7475″	0.0030″ to 0.0045″
Blower rotor thrust clearance		0.0025″ to 0.004″
Blower rotor clearances:		
Between rotor lobes		See "Timing Blower Rotors," Section S
Endwise—rotor to front end plate		0.0095″ to 0.0155″
Radial—rotor lobe to housing bore		0.018″ to 0.020″
Lubricating oil pumps:		
Backlash—all gear rotors		0.012″ to 0.016″
Radial clearance between gear teeth and housing bore		0.008″ to 0.011″
Side clearance between ends of gear teeth and ends of housing bore		0.005″ to 0.007″
Bearing clearance		0.0025″ to 0.005″
Fuel oil pump:		
End clearance between idler and head		0.001″ to 0.003″
Fresh water and sea water pumps:		
Clearance in diameter between impeller and casing rings		0.030″ to 0.035″

LUBRICATING OIL AND FUEL OIL SPECIFICATIONS

Lubricating Oil Specifications. Lubricating oil should be obtained from reputable oil companies to meet the following specifications for Diesel Engine lubrication:

Saybolt Viscosity at 100° F. *(See Note)	1000″ maximum
Saybolt Viscosity at 210°	75″ min. to 90″ max.
Flash	420° F. minimum
Fire	475° F. minimum
Pour	40° F. maximum
Carbon Residue	1.1% maximum

This oil must not contain organic acids, saponifiable oils, soaps, or other additional agents, that may cause corrison, and must not develop acidic compounds under operating conditions.

The lubricating oil used should have the proper body in order that it may be readily pumped through the bearings. An oil too heavy in body will not flow readily, resulting in poor distribution and the formation of carbon deposits within the cylinders. An oil too light in body will fail to maintain a complete oil film on the bearings and cylinders. Experience has proved that the continued efficient operation of an oil engine depends not only on intelligent care and proper fuel, but also very largely on correct lubrication.

**Note*: The requirement of 1000 seconds maximum at 100° F. is included in this specification to insure that the oil will not be too thick at low temperatures. In services where low temperatures are not encountered, this requirement is not essential. However, the viscosity of the oil at starting temperature should never exceed 30,000 seconds Saybolt.

Fuel Oil Specifications. The fuel oil shall be a petroleum distillate free from alkali, mineral acid, gum, and fibrous or other foreign matter. It should be obtained from reputable suppliers to meet the following specifications:

Ignition Quality	40 Cetane No., min.
Flash Point (ASTM D 93)	150° F. min. or legal
Viscosity at 100° F. (ASTM D 88)	35 min.-70 max.
Pour Point (ASTM D 97)	35° F. max.
Sulphur (ASTM D 129)	1% by weight, max.
Water and Sediment (ASTM D 96)	0.1% by volume, max.
Carbon residue (ASTM D 189)	0.15% by weight, max.
Ash	0.02% by weight, max.

INSTALLATION OF ENGINE

Installation. When intalling the engine the following items should be checked:

1. The foundation to which the engine is bolted must be level within 1/32" diagonally and longitudinally. Correct alignment can be attained by inserting metal shims between the bottom of the engine base and the engine foundation.
2. Secure engine base to engine foundation.
3. Whenever possible install cone type temporary strainers in the lubricating oil, fuel oil and sea water lines prior to the first start of the engine.
4. The attached sea water pump must be below sea water level to insure positive priming and supply.
5. All water, lubricating oil and fuel oil piping must be free of dirt, pipe scale and other obstructions before installing. Make sure that all flanges have flat surfaces and are air tight when bolted together.

Engine and Generator Alignment. The procedure for aligning the engine and generator is as follows:

1. If generator has not been installed on engine base this should be done as follows:
   a. Measure and record the axial thrust clearance of the generator thrust bearing, the engine thrust bearing, and the elastic coupling. Do not spring the elastic coupling disc when taking this reading.
   b. Insert shims between the armature and field of the generator to center the armature in the field.
   c. Place the generator on the base and move into the coupling position until the coupling faces are about 1/4" apart.
   d. Align the driving dowel holes in the generator flange and the elastic coupling outer disc by adjusting the generator laterally and vertically.
   e. Move the generator armature shaft and the engine crankshaft away from each other to the limit of clearance in both thrust bearings. Pry the elastic coupling toward the engine to the inner limit of its axial clearance.
   f. Move the generator toward the engine until the distance between the coupling flanges is equal to one-half of the total axial clearance of the armature shaft, the crankshaft and the elastic coupling. Take readings between the coupling faces to be sure that the distance is correct and that the flange faces are parallel and in line.
   g. Secure the generator flange to the elastic coupling flange.
2. Place strain gauge between engine crankshaft cheeks nearest the generator, as shown in Fig. 1D. Strain gauge readings should be taken as illustrated. These readings should agree within 0.0035" maximum, 0.0015" preferred. If not, loosen the generator hold-down bolts and remove locating dowels.

   Note: Install the strain gauge as shown in Fig. 2D with its two end-points in the crankshaft prick-punch marks. Turn the crankshaft into the first position where the gauge will be as close to the top as possible, without touching the connecting rod. Set the dial to zero, then turn crankshaft and take readings at positions

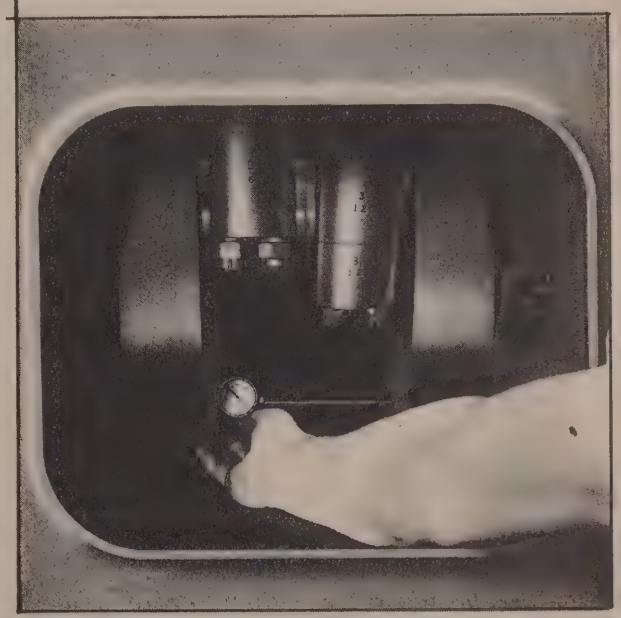


Fig. 1D
Proper Position of Strain Gauge when Measuring Crank Cheek Deflection

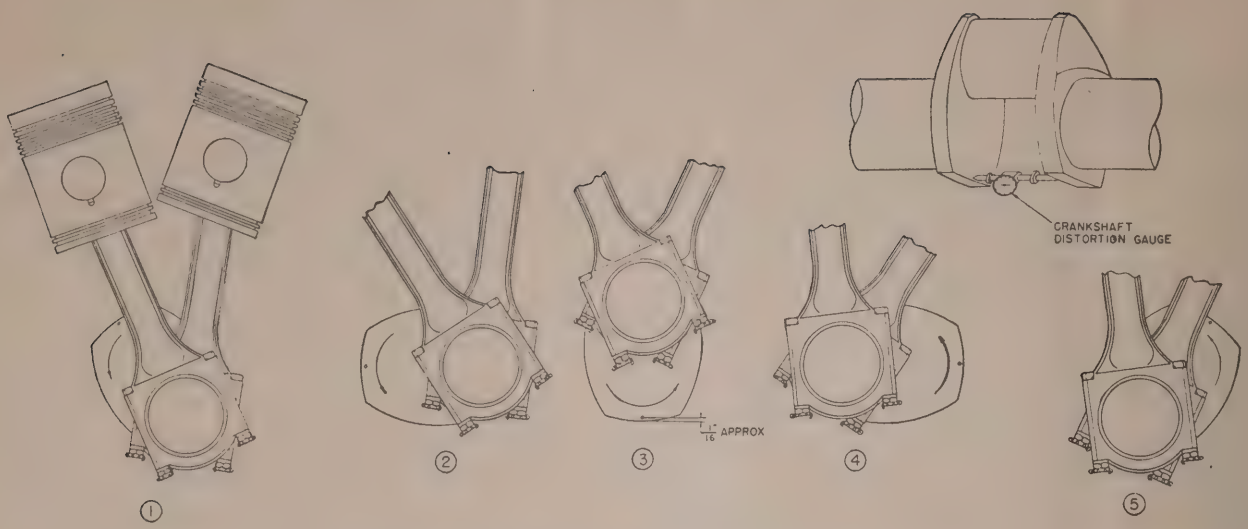


Fig. 2D
Positions of Crankshaft for Strain Gauge Readings

2, 3, 4 and 5. Make sure that the strain gauge does not rotate about its end points, relative to the crank cheeks. When the lowest position (3) is reached, the dial of the gauge will be upside down and a small mirror and flashlight will be needed to read the dial. Once the dial has been placed in the first position and set at zero, no portion of the gauge should be touched until all four readings have been taken.

If a new crankshaft is to be installed, or if the prick-punch marks are not on the old shaft, they should be made as follows:

With a straight edge, draw two aligned reference lines, one on the flat portion of the side of each cheek, 180° from the crankpin. At each of these lines, make a prick-punch mark on the face of each cheek approximately $\frac{1}{16}$" from the edge.

3. Then adjust the two jacking screws near the rear end of the generator until strain gauge readings show the proper values.
4. Then adjust the two jacking screws near the front end of the generator until the air gap between the armature and the field coils is equal around the circumference of the armature.
5. Insert proper amount of shims between generator and base. Install dowels and tighten bolts. Check strain gauge readings again.
6. Pry engine crankshaft forward and backward through its total thrust clearance and be sure generator bearing does not strike either stop on armature journal.

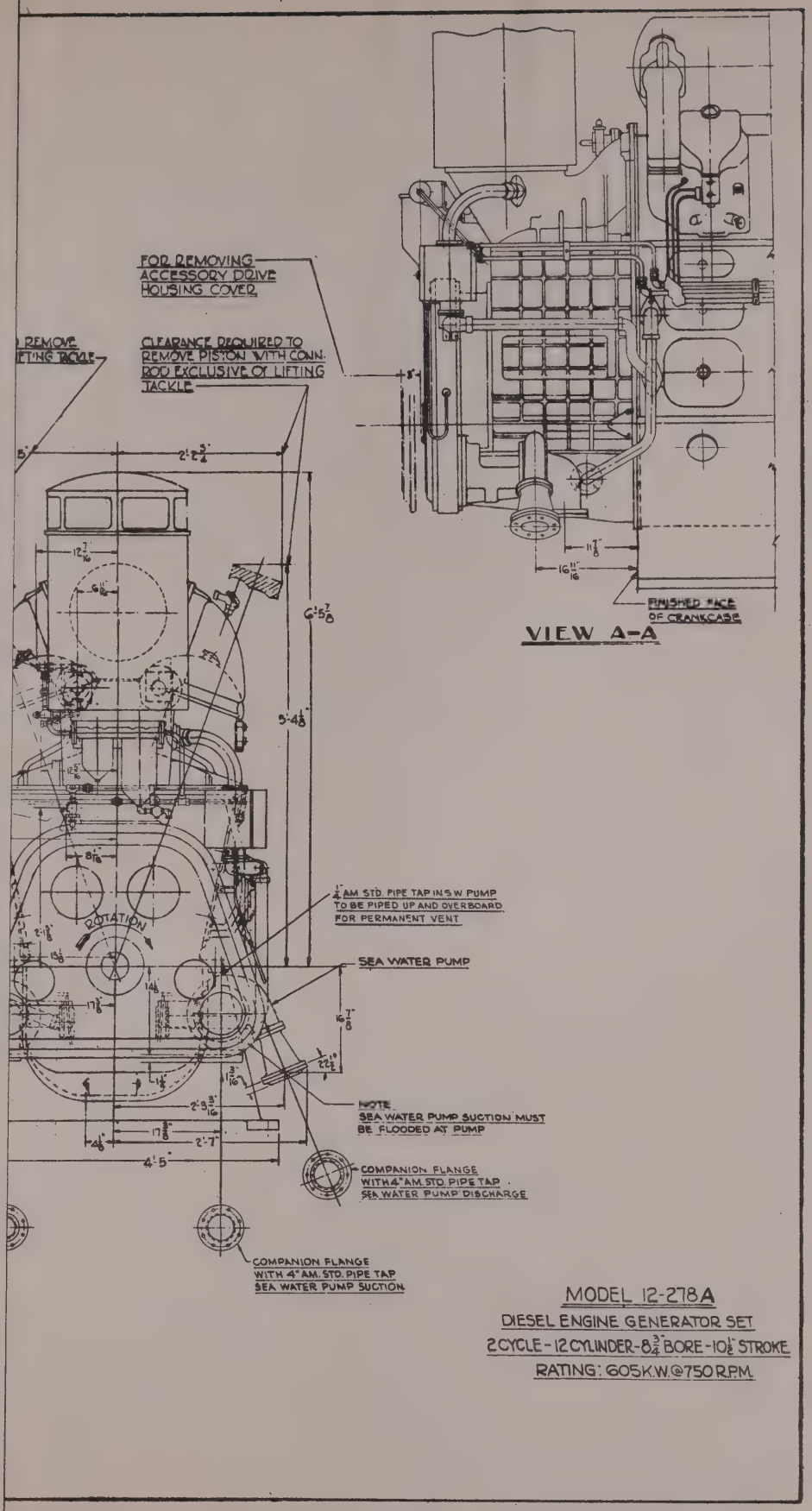
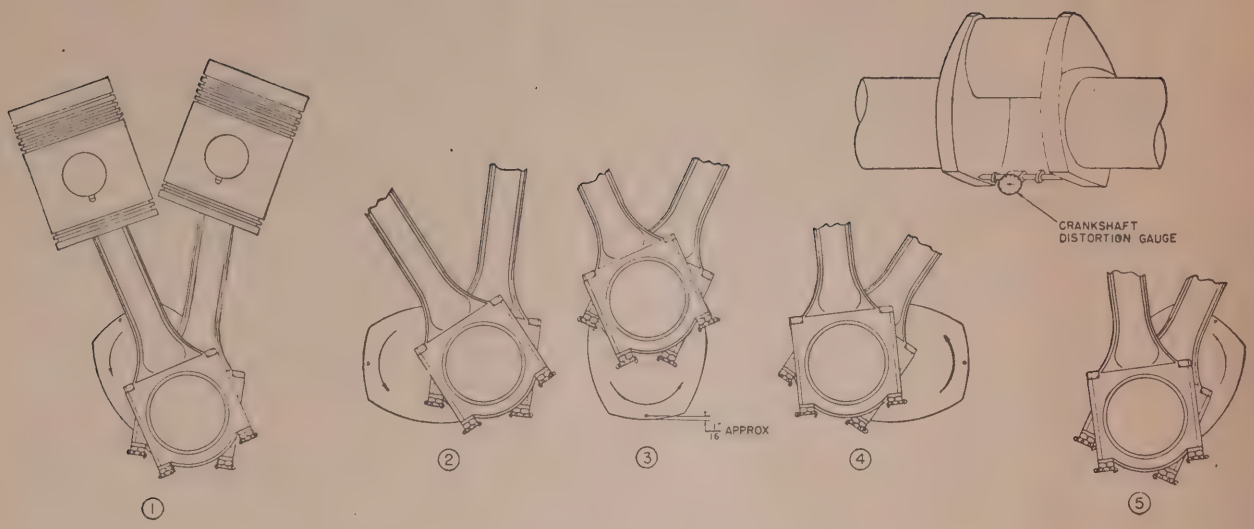

FOR REMOVING ACCESSORY DRIVE HOUSING COVER
CLEARANCE REQUIRED TO REMOVE PISTON WITH CONN. ROD EXCLUSIVE OF LIFTING TACKLE
REMOVE LIFTING TACKLE
VIEW A-A
FINISHED FACE OF CRANKCASE
ROTATION
SEA WATER PUMP
AM. STD. PIPE TAP IN S.W. PUMP TO BE PIPED UP AND OVERBOARD FOR PERMANENT VENT
NOTE SEA WATER PUMP SUCTION MUST BE FLOODED AT PUMP
COMPANION FLANGE WITH 4" AM. STD. PIPE TAP SEA WATER PUMP DISCHARGE
COMPANION FLANGE WITH 4" AM. STD. PIPE TAP SEA WATER PUMP SUCTION
MODEL 12-278A
DIESEL ENGINE GENERATOR SET
2 CYCLE - 12 CYLINDER - 8 3/4" BORE - 10 1/2" STROKE
RATING: 605 K.W. @ 750 R.P.M.

Fig. 3D



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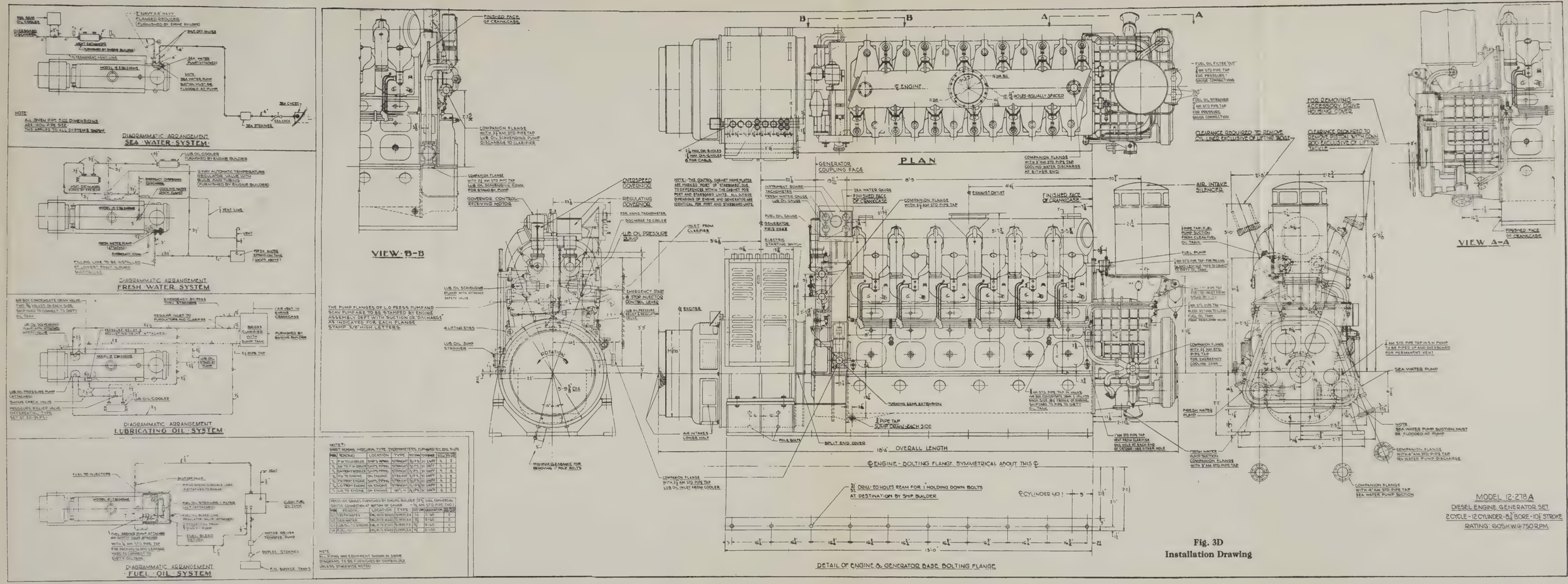

DIAGRAMMATIC ARRANGEMENT SEA WATER SYSTEM
DIAGRAMMATIC ARRANGEMENT FRESH WATER SYSTEM
DIAGRAMMATIC ARRANGEMENT LUBRICATING OIL SYSTEM
DIAGRAMMATIC ARRANGEMENT FUEL OIL SYSTEM
VIEW B-B
PLAN
VIEW A-A
DETAIL OF ENGINE & GENERATOR BASE BOLTING FLANGE
MODEL 12-278A
DIESEL ENGINE GENERATOR SET
2 CYCLE - 12 CYLINDER - 8½ BORE - 10½ STROKE
RATING: 605 KW @ 750 RPM.

Fig. 3D
Installation Drawing

Fig. 3D

ENGINE OPERATION AND ADJUSTMENTS

Engine Adjustments. Before starting the engine after a long period of idleness, or after any repairs have been made on the engine, the following procedure should be observed and the prescribed adjustments made:

1. Check the injector linkage for binding. This can be done by removing the clevis pins at the end of each injector control shaft and then turning the shaft back and forth by hand. If any of the injector racks are not free, the tension will be felt when the shaft is turned, indicating that probably either the individual plungers and gears are binding, or that the slip-joint from the injector control shaft to the individual injector rack is bent or is not aligned properly with the injector rack. Remove the clevis pins from the governor power piston tail rod and the lubricating oil pressure regulating valve and operate this section of the linkage by hand. If a bind is indicated, remove the remaining clevis pins one by one until the point of bind is located. Correct reason for bind.

2. Remove the cylinder head covers, (Fig. 1J), exposing the injector micrometer adjusting screws, and set the adjusting screws midway in the range governed by the number of turns from full open to closed. (See Fig. 2E.)

3. Check injector linkage for correct adjustment. Be sure hand control lever is latched in the "RUN" position. Remove the clevis pins holding the cross tie rods to the injector control shaft levers on each bank and manually turn the injector control shafts so that the injector racks are placed in the stop position, but not with sufficient force to compress the springs in the slip-joint links. With the governor power piston pulled all the way down, spread the governor flyballs manually to allow the power piston to move to the extreme fuel off position. Release the flyballs and the power piston should maintain its position. If the holes in the end of the cross tie rods line up with the holes in the control shaft lever, insert the clevis pins. If the holes are out of alignment an equal amount on each bank, adjust the length of the control rod attached to the governor power piston tail rod until the holes are aligned. If the holes are out of alignment an unequal amount, adjust the length of the cross tie rods until the holes are aligned.

   Remove clevis pin from connection of link from hand control to injector linkage. Latch the hand control lever in the "Stop" position. Adjust the length of the connecting link so that the clevis pin holes line up. The clevis pin should slide in easily without springing the linkage.

4. Remove the governor cover and fill governor with oil until the gauge glass on the side of the governor is half full. Close compensating needle valve and then open ½ turn. When a new or rebuilt governor has been installed the governor adjustments on page E-4 should be noted carefully.

5. Time the injector plunger stroke of cylinder No. 1 with engine, by turning the crankshaft with the turning gear in the direction of rotation to bring No. 1 crankpin in the timing position at 7° before top dead center as indicated by the markings on the elastic coupling. By adjusting the rocker lever screws, set the injector with the special height gauge as shown in Fig. 1E.

   Note No. 1: It is not necessary to set the injector rack at any particular position, as only the plunger stroke movements are timed to inject a metered quantity of fuel at the predetermined and most effective part of the cam lift.

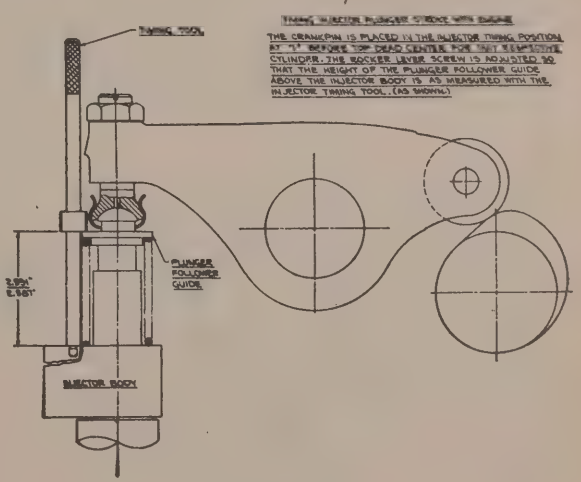


Fig. 1E
Timing Injector

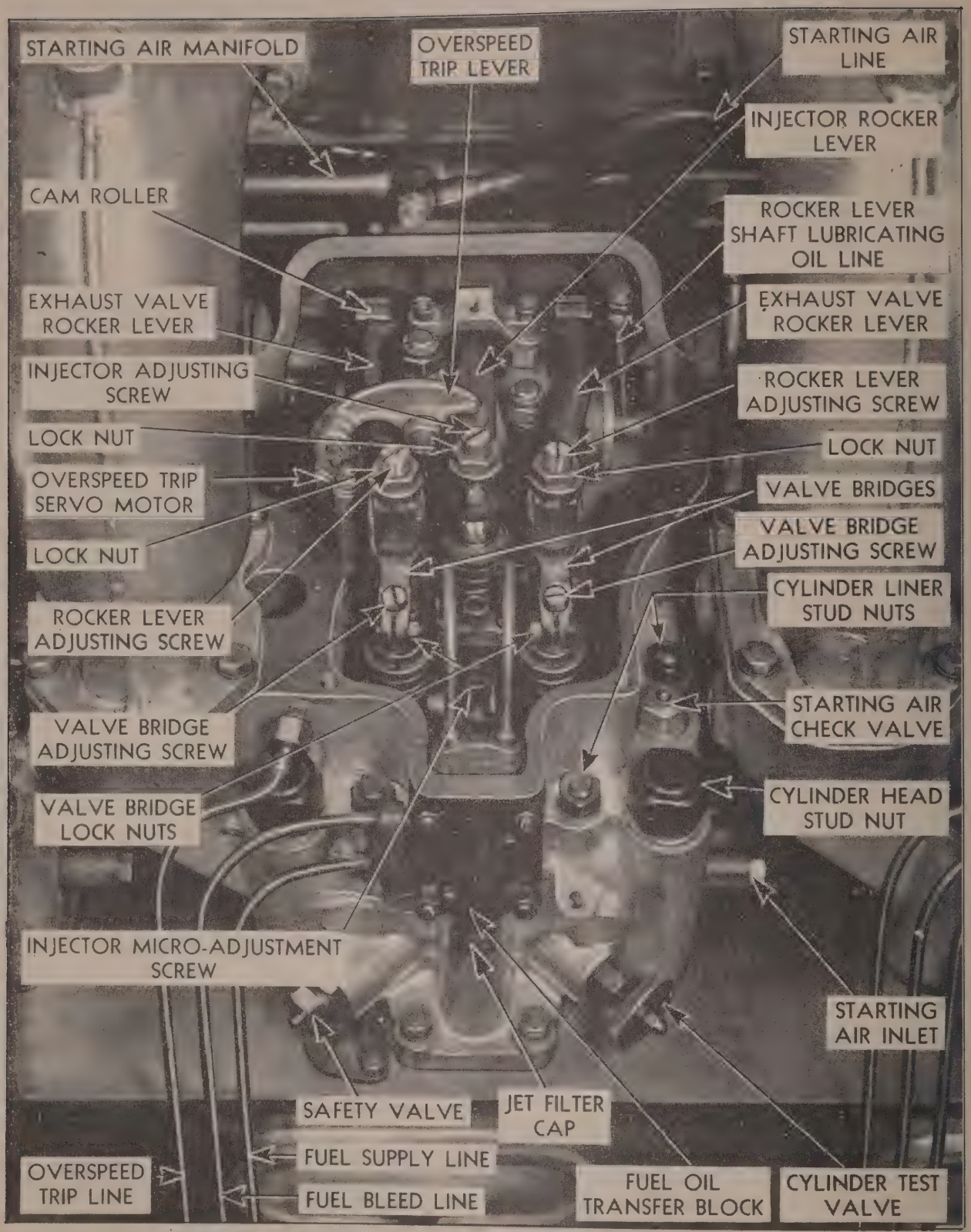


Fig. 2E
Cylinder Head and Rocker Lever Assembly

Note No. 2: When turning the crankshaft always preserve the backlash of the gears in the same direction. If the 7° before TDC mark is overshot, return against rotation to at least 30° before TDC and then come up to the 7° mark.

6. With the engine cold, set the exhaust valve stem clearance at 0.015". This can be done after timing the injector for that particular cylinder (No. 1) as outlined above, without moving the crankshaft. Loosen the lock screws on the valve bridges and tighten the valve adjusting screws until they just touch the valve stem caps, but do not tighten enough to open the valves. Using a feeler gauge between the valve bridge adjusting screws and the valve stem caps, set the clearance by adjusting the screw on the valve rocker arm. Tighten the locknut and check valve clearance.
7. Time the injectors and set valve clearance of remaining cylinders.

Preparations for Starting the Engine. Before starting the engine, the following items should be checked:

1. Check all fuel, water, and oil pipe lines for blank flanges.
2. Fill the engine with fresh water until the expansion tank is three quarters full.
3. Check for leaks around liner in air box.
4. Open sea water valves.
5. Vent air from water pumps by opening petcock on top of each pump and keeping it open until all air has been expelled.

   Note: If a permanent bleed is installed, it is not necessary to vent the sea water pump by this method.
6. Drain scavenging air box by opening air box drain valves, located between the air box and crankcase handhole covers at each end of both cylinder banks.
7. Check fuel supply for traces of condensate by drawing from bottom of tank until clean fuel oil flows.
8. See that fuel oil filter and strainer are clean.
9. Open fuel supply valve.
10. Prime lubricating oil system with hand pump and check for leaks.
11. Remove cylinder head covers and pour at least one quart of clean engine oil over the valve mechanisms of each cylinder head.
12. Check exhaust line to see that it is open and unobstructed.
13. Open cylinder test valves on side of cylinder heads. (See Fig. 2E.)
14. Place hand control lever in "Stop" position.
15. Turn crankshaft one or more revolutions with the turning gear to make sure there are no obstructions. Disengage the turning gear.
16. Place generator cutout switch lever in "by-pass" position and press starting push button to crank the engine, observing if after five seconds there is any excess of water or fuel oil vapor being emitted from the cylinder test valves. Before securing the test valves, and attempting to start the engine, the source of any excess fuel or water must be determined and corrected.
17. See that oil in governor is at correct level.
18. Be sure that remote electrical control in the pilot house is set at no load.

Starting the Engine. (See also "Starting after Repairs," page E-4.)

1. Close the cylinder test valves.
2. Be sure generator cutout switch is in "by-pass" position.
3. Hold the hand control lever in the "start" position, and press starting push button. The engine should fire within 10 seconds. Release starting push button when engine fires.
4. Control the speed of the engine with the hand control lever until governor oil pump has built up a working pressure.
5. Check lubricating oil pressure. If pressure is not indicated on gauge within 10 seconds stop engine and determine cause.
6. Check sea and fresh water pressure to make sure water is being circulated.
7. Place the hand control lever in the "run" position.
8. When control voltage has been established, operate release knob and move generator cutout switch lever to "propulsion" position.

Running the Engine. (See also "Starting after Repairs.")

1. Check lubricating oil pressure gauges to be sure that engine is receiving oil under pressure. The oil pressure should be between 8 and 12 pounds per square inch at 375 r.p.m. Adjust if neces-

sary. See "Pressure Regulating and Relief Valves," Section P. Check expansion tank level and circulation of cooling water by watching gauges.

2. Check to see that the lubricating oil pressure is 40 to 50 pounds per square inch, at full load and speed. Adjust if necessary. See "Pressure Regulating and Relief Valves," Section P.
3. Check the circulation of the cooling water. The pressure of fresh water to engine should be 24 to 37 pounds per square inch; sea water to coolers 19 to 35 pounds per square inch. Check the fuel oil pressure and, if necessary, adjust the relief valve in the bleed line to obtain from 40 to 50 pounds per square inch.
4. Measure the temperature of the exhaust from each cylinder with a pyrometer and compare the temperature with that of the other cylinders. The difference between any two cylinders should not exceed 50° F. at full load and speed. Increase or decrease the temperature of any cylinder by resetting the micrometer adjusting screw (see Fig. 2E) connected to each injector control rack. Turning the adjusting screw to the right injects less fuel and to the left, more fuel, at full speed and full load the exhaust temperature of any cylinder should not exceed 400° to 500° F.
5. Check to see that the temperature of the fresh water leaving engine is 140° F. Adjust temperature at the temperature regulator to secure temperature. (See "Temperature Regulator," Section R.)
6. Check to see that the temperature of the lubricating oil leaving the engine is between 140° F. and 180° F. The preferred temperature is 165° F.
7. Drain air box after every 2 hours of engine operation.

Stopping the Engine.

1. After the propulsion machinery has been stopped, the engine should be running at 375 r.p.m. under governor control.
2. Allow the engine to idle for about one minute.
3. Stop the engine by raising the hand control lever to the "Stop" position.
4. If an emergency should arise, the engine may be stopped quickly by raising the hand control lever to the "Stop" position, or by pressing down the small shutdown button on the cover of the speed regulating governor and holding it down until the engine stops.

Starting after Repairs. If the engine has been repaired, the adjustments under "Engine Adjustments," page E-1, should be made before starting the engine. It is good practice to run the engine slowly under a light load, and with frequent inspections to determine if the renewed parts are satisfactory.

The speed and load should be increased gradually up to full load and speed with an elapsed time of about 8 hours for running-in the new parts.

If the engine has been idle for a long period, a short run-in period is recommended.

Governor Adjustments

Three adjustments are provided on the governor: speed control, compensation, and B.M.E.P. limitation.

Speed Control. The speed of the engine is regulated by means of the governor speed control shaft which is controlled by the remote control system. This increases or decreases the compression of the speed adjusting spring that opposes the centrifugal force of the governor flyballs.

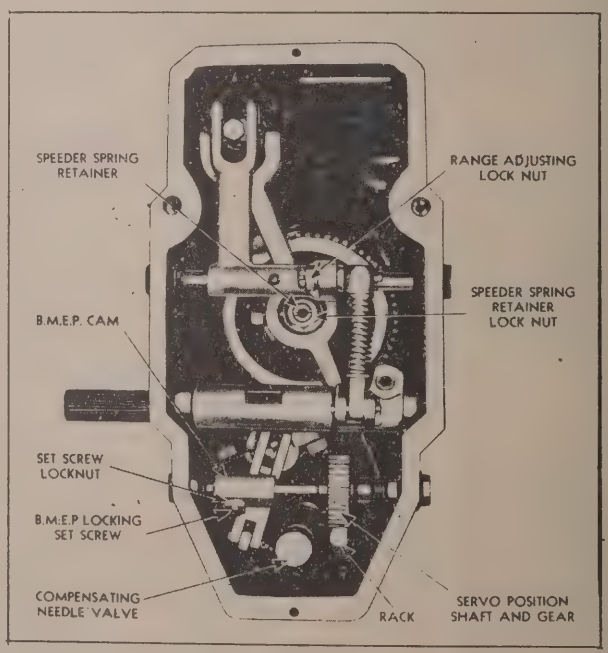


Fig. 3E
Top View of Governor

1. Set the idle speed and full speed stop screws so that they protrude about ¼" inside the quadrant cover.
2. With the engine stopped, energize the remote control circuits while the speed controller remains in the off position.
3. Engage the receiver pinion with the governor quadrant so that a slight downward force is exerted by the pinion on the quadrant to be sure quadrant contacts stop screw.
4. Start the engine. Run the engine under governor control at no load and record engine speed with the quadrant at the idle speed stop.
5. Turn the engine speed controller handwheel to the full speed position and note engine speed.
6. The difference between the idle speed and full speed should be 375 r.p.m. regardless of full speed and idle speed r.p.m. If not, remove governor cover, loosen castellated nut holding spring link to the auxiliary speed control lever. (See Fig. 3E.) To increase speed range, move the spring link downward in slot. To decrease speed range, move upward. After each adjustment, repeat steps 4 and 5 until the speed range is exactly 375 r.p.m. full speed, minus idle speed.
7. With engine speed controller handwheel in full speed position, adjust the governor speeder spring retainer nut until engine speed is 750 r.p.m. at no load. (See Fig. 3E.) Replace governor cover. Turn engine speed controller handwheel to the idle speed position. The idle speed may be approximately 375 r.p.m. A slight adjustment may be necessary. This can be done by adjusting the idle speed stop screw.

Compensation. The compensation adjustment is provided to prevent hunting (speed departure) when the load or engine speed is changed. Adjustment is made by means of the small knurled knob inside the governor. (See Fig. 3E.)

1. Remove governor cover by turning the large knob on the top of governor to the left until it contacts the stop and turns the locking bar.
2. With the engine running at full speed and full load, momentarily decrease the speed and then quickly move the engine speed controller handwheel to the full speed position. The engine speed should return quickly to its normal speed without overshooting or hesitating. If engine speed overshoots excessively, close compensating needle valve slightly. If engine speed returns to normal too slowly, open compensating needle valve slightly.
3. Replace governor cover.

B.M.E.P. Limitation. The B.M.E.P. limiter is provided to prevent overloading the engine at any speed. Adjustment is made by means of the cam adjacent to the speed control shaft.

1. Remove governor cover.
2. Loosen locknut and setscrew. (See Fig. 3E.)
3. With engine running at full speed increase load to 110%.
4. Rotate cam toward center of governor until the B.M.E.P. push rod starts to move downward, decreasing engine speed.
5. Tighten setscrew and locknut.
6. Replace governor cover.

Operating Difficulties

Engine Will Not Start When Cranked at Proper Speed.

1. Check fuel supply to cylinders by opening test valves and cranking engine with hand throttle in the starting position. A dense spray of fuel oil should be emitted from each cylinder test valve discharge hole.
2. Inspect exhaust valves to determine if some of them are stuck open or have improper clearance. Loss of compression results, causing misfiring in the affected cylinders.
3. Injectors may be incorrectly timed.

Low Lubricating Oil Pressure — STOP ENGINE.

1. Check oil supply in oil pan or sump tank.
2. Check for oil dilution.
3. Filter, supply line strainer or cooler may be clogged. Check and clean.
4. Spring loaded relief valve or regulating valve at inlet to engine may be by-passing lubricating oil. Check, clean and readjust.
5. Lubricating oil pump worn. Check and renew parts if necessary.
6. Gauge lines clogged or valve shut off.

Excessive Use of Lubricating Oil.

1. Check for stuck piston rings.
2. Check for worn pistons, piston rings, or liners.
3. Oil leaking into water side of cooler.

Fuel Dilution of Lubricating Oil.

1. Check to see that fuel jumper tubes to injector are not cracked and are seated properly.
2. Check injector filter cap gaskets for leaks.
3. Check for stuck piston rings.
4. Check injector for leaks.

High Lubricating Oil Temperature.

1. Check oil pressure and level.
2. High fresh water temperature.
3. Low sea water flow. (Check pressure.)
4. Oil cooler may be clogged. Check and clean.
5. Check temperature regulator setting and operations.

High Fresh Water Temperature.

1. Check level in expansion tank.
2. Low fresh water flow. (Check pressure.)
3. Check temperature regulator setting and operation.

Low Fresh Water Pressure.

1. Stop engine and vent engine driven pump through petcock located on pump housing.
2. Check all flanges on the suction side of the pump. Air admitted to the system will reduce the efficiency of the pump.
3. Check fresh water cooler for obstructions or silt.

Low Sea Water Pressure.

1. Pump may be air bound. Stop engine and vent through petcock located on pump housing.

   Note: If permanent overboard vent line has been installed on pump housing check to see that it is open.
2. Stop engine, check source of supply for clogged strainer or coolers.

Low Fuel Oil Pressure.

1. Check supply.
2. Check fuel oil relief valve for dirt.
3. Check strainer and filter for dirt or obstructions.

Speed Departure (Hunt).

1. Check for erratic fuel oil pressure. Relief valve may be binding.
2. Inspect governor to make sure that regulating pilot valve is rotating at all speeds. This can be observed by removing the governor cover and noting the rotation of the pilot valve bearing retainer nut located inside the speed adjusting spring.
3. Check injector control shaft linkage for binding.
4. Check oil level in governor.
5. Check compensating needle valve adjustment.

Engine Will Not Shut Down.

1. Injector linkage may be improperly adjusted. See "Engine Adjustments," page E-1.
2. Injector rack may be stuck or incorrectly meshed with injector gear. In order to stop engine remove cylinder head cover and hold injector rocker lever down with screwdriver, or overspeed engine.

Unequal Exhaust Temperatures.

1. Adjust micrometer screws on injector slip link as per Item No. 4 under "Running the Engine."
2. Check for stuck slip link on injector control shaft or stuck injector rack.
3. If cylinder temperature is low, remove and check injector.
4. If cylinder temperature is high, check for stuck exhaust valves and insufficient valve clearance.
5. Take compression pressures on individual cylinders.

Excessive Vibration.

1. Check for loose main bearing and connecting rod caps.
2. Check exhaust temperatures for wide variation.

Excessive Exhaust Temperatures In All Cylinders and Loss of Speed.

1. Check electrical load.
2. Check silencer screen for cleanliness.

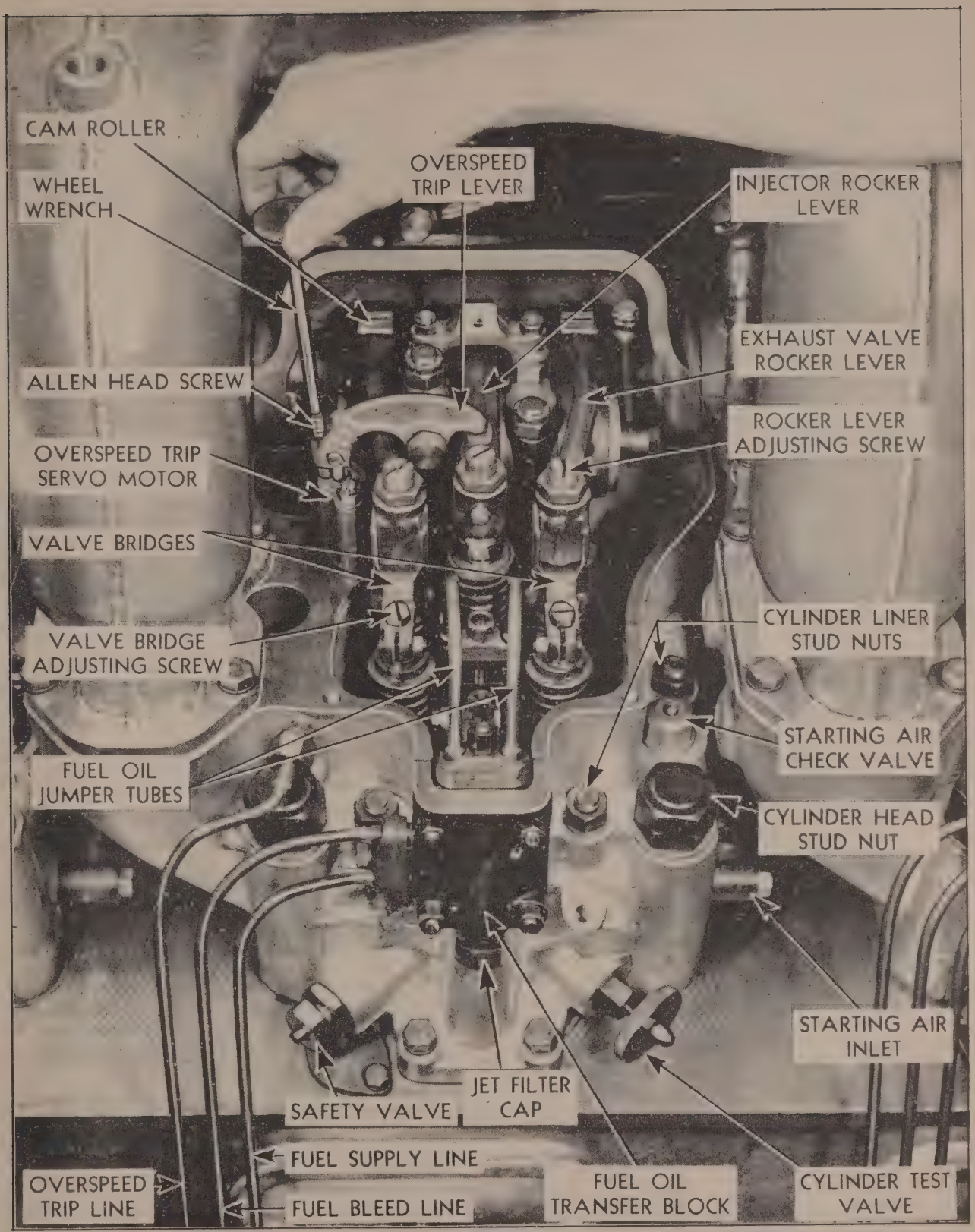


Fig. 4E
Method of Locking Out Injector

3. Check for sticking exhaust valves.
4. Check for high exhaust back pressure.
5. Check water circulation.
6. Check governor adjustments. (See Page E-4.)

Loss of Power.

1. Check exhaust temperatures to see that all cylinders are firing.
2. Fuel pump may be air bound—check supply.
3. Check fuel oil pressure.
4. Check compression pressures.
5. Check for obstructions in exhaust line.

Low Compression Pressures.

With maximum pressure indicator carefully check compression on individual cylinder as follows:

1. Run engine at full speed and no load.
2. Shut off fuel to cylinder being tested by depressing injector rocker lever with screw inserted in overspeed trip servo-motor clevis.

Compression pressures on a new engine should vary from 550 to 650 pounds per square inch. When pressure for any cylinder drops below 450 pounds per square inch the following checks should be made:

1. Check for stuck exhaust valves.
2. Check for stuck piston rings.
3. Check for leaking cylinder head to liner gasket.

Stuck Exhaust Valve.

1. Valve stem may be gummed.
2. Valve stem may be bent.

Note: To loosen stuck exhaust valve bring piston to top dead center, being careful not to damage valve head; remove spring seat, cap, spring lock, and spring; free valve by applying penetrating oil, rotate and work valve up and down.

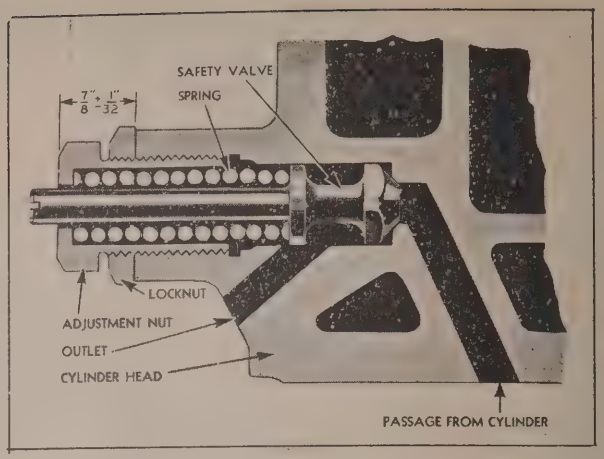


Fig. 5E
Cylinder Safety Valve

After the valve has been freed the exhaust temperature should be checked. If the exhaust temperature of the cylinder that had the stuck valve is excessive, the valve has been burned and should be renewed.

Excessive Firing Pressures.

Note: The firing pressures at full speed and load on a new engine vary from 850 to 1050 pounds per square inch as measured with a maximum pressure indicator.

1. Check electrical load.
2. Injector may be incorrectly timed.

Safety Valve Popping.

1. Screw in adjusting nut until popping ceases, then check firing pressures at full load.

Note: If popping will not cease, stop engine, renew safety valve spring and adjust valve so that adjusting nut protrudes 7/8" from cylinder head. (See Fig. 5E.)

CYLINDER BLOCK AND CRANKSHAFT

Cylinder Block

Description. The cylinder block is the main structural part of the engine. It is fabricated from forgings and steel plates welded together, combining strength with light weight.

The upper and lower decks of each bank are bored to receive the cylinder liners. The space between the decks and the space between the two banks form the scavenging air chamber. The cylinder liner bore in the lower deck of each bank serves as a cooling water inlet ring for each liner.

The forged transverse members at the bottom of the cylinder block form the mounting pads for the main bearing seats. The camshaft bearing lower seats are an integral part of the cylinder block. The bearing seats and caps are match-marked and must be kept together.

Removable handhole covers close the openings in the sides of the cylinder block. Access to the injector control shaft is obtained by removing the top row of small handhole covers. The middle row of handhole covers permits access to the scavenging air box for inspection of the cylinder liner and piston rings. The bottom row of handhole covers permits access to the crankshaft connecting rods, and bearings.

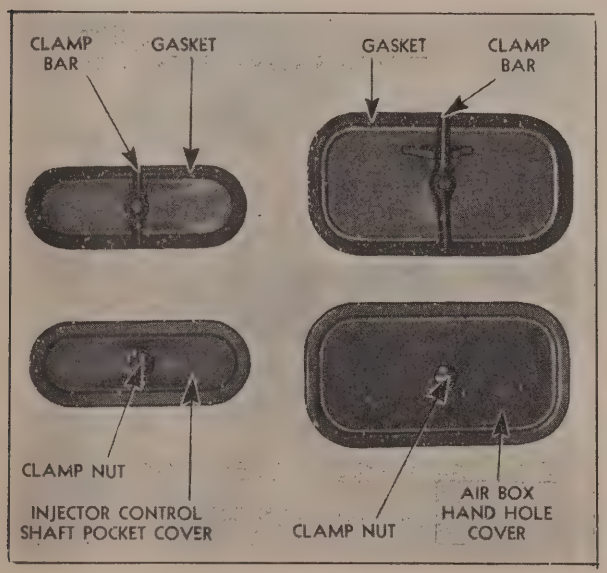


Fig. 1F
Injector Control Shaft and Air Box Handhole Covers

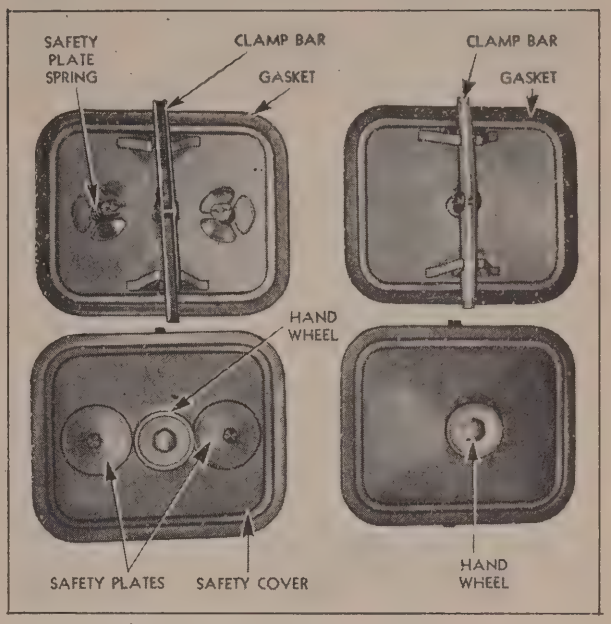


Fig. 2F
Crankcase Handhole Covers

The main bearings are lubricated from the lubricating oil manifold attached to the main bearing supports.

Maintenance. After disassembly and before any parts are reassembled to the cylinder block, the block should be thoroughly cleaned. Clean the air box with carbon tetrachloride, or a similar cleaner, and blow dry with compressed air.

Inspect the block thoroughly for any condition which would render the part unfit for further use. Use new gaskets when reassembling.

Engine and Generator Base

Description. The welded steel engine and generator base is bolted to the bottom of the cylinder block and serves as an engine and generator base and oil pan.

The lower camshaft drive housing is fastened to one end of the base and returning lubricating oil

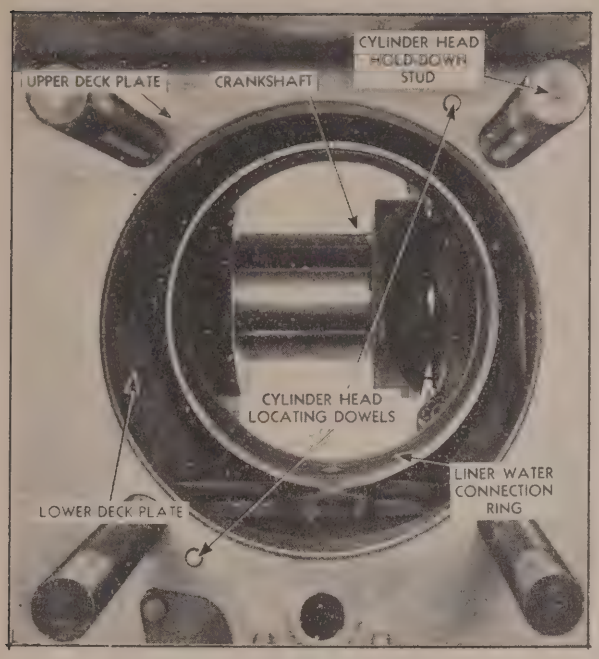


Fig. 3F
Crankshaft Through Liner Hole

drains from this housing into the oil pan. The blower bottom housing is fastened to the other end of the oil pan, and the returning oil from the blower and blower drive housing drains through the blower bottom housing into the oil pan.

Crankshaft

Description. The crankshaft is a heat-treated alloy steel forging finished on the bearing surfaces only. The crankshaft consists of 6 crankpin throws 60° apart and seven main bearing surfaces. The rear main bearing acts as a combined main and thrust bearing.

Lubricating oil is supplied from the manifold mounted below the main bearing supports. The lubricating oil flows through the main bearing support to the main bearings. From the main bearings, oil flows to the two adjoining crankpin bearings through drilled holes in the crankshaft and lubricates the connecting rod bearings.

The elastic coupling is attached to the crankshaft at the drive end.

Maintenance. The only maintenance required on the crankshaft is the inspection of the main and connecting rod bearing surfaces. In case it is necessary to change a main bearing shell, the crankshaft journal should be examined carefully for signs of overheating, scoring or excessive wear. If the crankshaft is damaged to such an extent that continued operation would result in damage to the associated parts, it should be renewed or reconditioned. When the crankshaft is removed from the engine, the oil passages in the crankshaft should be blown out with compressed air.

Remove Crankshaft.

1. Drain fresh water system.
2. Remove exhaust elbows. (See Section S.)
3. Remove exhaust manifold. (See Section S.)
4. Remove cylinder heads. (See Section J.)
5. Remove pistons and connecting rods. (See Section H.)
6. Disconnect fuel oil supply and bleed lines from ship's piping.
7. Remove blower. (See Section S.)
8. Remove generator.
9. Remove elastic coupling. (See page F-4.)
10. Remove upper camshaft drive housing cover and lower camshaft drive housing. (See Section K.)
11. Remove crankshaft gear and crankshaft idler gear. (See Section K.)
12. Remove bolts and dowels holding cylinder block to engine base.
13. Remove interfering piping.
14. Lift cylinder block off engine base.

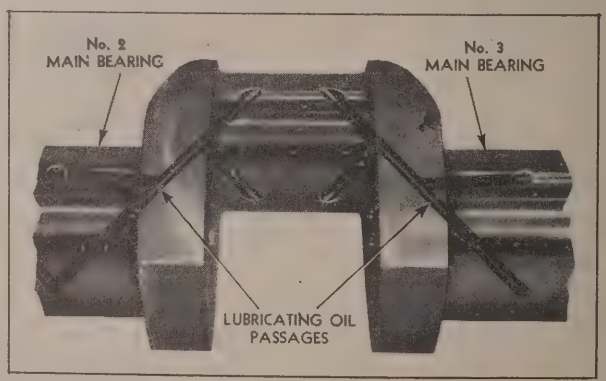


Fig. 4F
Crankshaft Showing Lubrication Passages

15. Support cylinder block and remove main lubricating oil manifold.
16. Remove jacking screws on all main bearing caps.
17. Lift off main bearing caps and upper main bearing shells.
18. Attach hoist to both ends of crankshaft and lift up into cylinder block.
19. Remove bolts from each main bearing support. (Keep nuts with bolts for reassembling.)
20. Slide main bearing supports off dowels.
21. Carefully lower crankshaft onto wooden blocks and lift off cylinder block.
22. Remove blower drive shaft coupling.

Install Crankshaft. The crankshaft is installed by reversing the procedure used to remove it. The following precautions should be noted:

1. Before installing crankshaft, thoroughly check shaft for nicks and burrs, polish all bearing surfaces and wipe clean. Thoroughly clean all oil passages with round brush and blow passages clean with air.
2. The main bearing supports should be installed without the lower bearing shells in place and the markings, (1, 2, 3, etc.), on the bearing supports must face the blower end of the engine. After the bearing supports have been installed, the lower bearing shells should be inserted, cleaned and oiled, carefully noting the markings on the edge of the bearing flange as described in Section G.

Elastic Coupling

Description. The elastic coupling is the connection between the engine and the generator. The power from the engine crankshaft to the driven shaft is transmitted through a number of spring packs from the inner ring of the coupling to the outer ring which is the driven member. The drive from the outer spring holder to the flange on the driven shaft is through a large driving disc which is bolted to both of these parts. Power is transmitted from the outer spring holder through this driving disc and to the driven shaft flange. A pilot on the end of the crankshaft fits into a bronze bushed bearing on the shaft driving disc, to center the driven shaft. The turning gear engages a ring gear shrunk on the rim of the outer spring holder.

The front driven flange, through which the camshaft gear train is driven, is fastened to the other

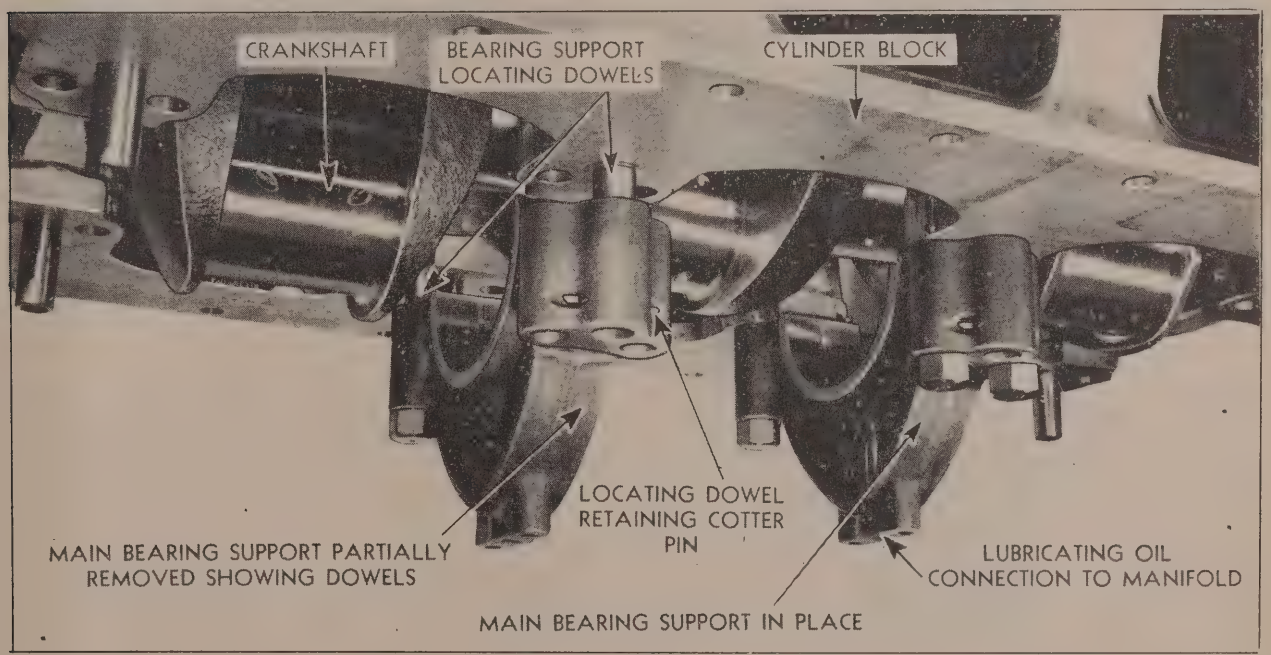

CRANKSHAFT
BEARING SUPPORT LOCATING DOWELS
CYLINDER BLOCK
LOCATING DOWEL RETAINING COTTER PIN
MAIN BEARING SUPPORT PARTIALLY REMOVED SHOWING DOWELS
LUBRICATING OIL CONNECTION TO MANIFOLD
MAIN BEARING SUPPORT IN PLACE

Fig. 5F
Installing Crankshaft

side of the outer spring holder. A spline ring is bolted to this driven flange. A helical internal gear is cut in the bore of the spline ring which fits on the outer part of the crankshaft gear teeth. This forms a splined drive connection to the crankshaft gear which has a loose mounting on the crankshaft. The spline ring is split and the two parts bolted together with a spacer block in each split-joint that replaces a helical spline tooth. This makes it possible to separately engage the two parts of the spline ring with the crankshaft gear teeth at the inner end of the gear, and to slide them into position with the idler gear in place.

The parts of the elastic coupling are lubricated with oil that flows from the bearing bore of the crankshaft gear and from the pilot bearing. These bearings receive oil that flows from the adjacent main bearing through passages in the crankshaft.

Maintenance. With the spring packs removed, neither the inner nor outer spring holder should be rotated. Rotation of either spring holder independent of the other, transmits motion to the crankshaft, or the camshaft, depending upon which spring holder is moved, with the result that the exhaust valves will be damaged by the pistons. If it is necessary to rotate either spring holder, the rocker lever assembly in each cylinder head must be removed.

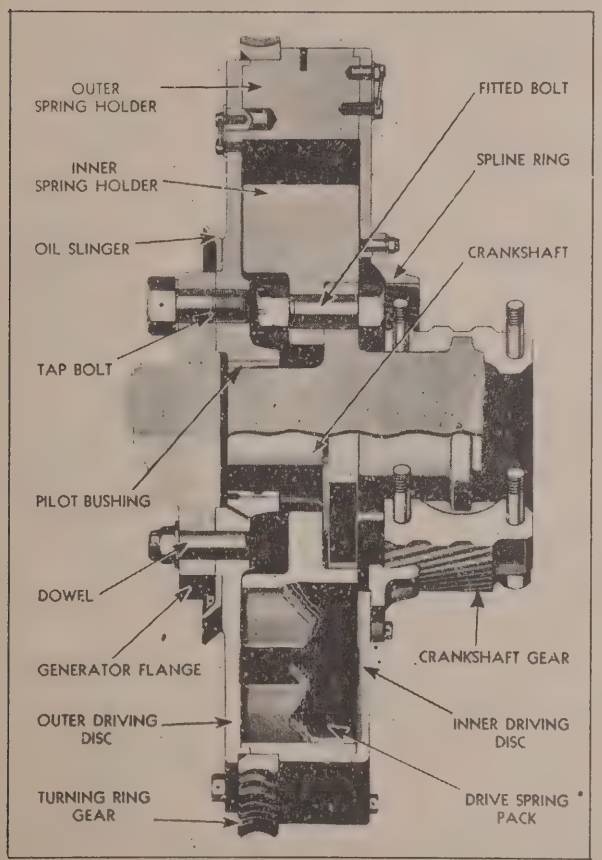


Fig. 6F
Elastic Coupling Cross Section

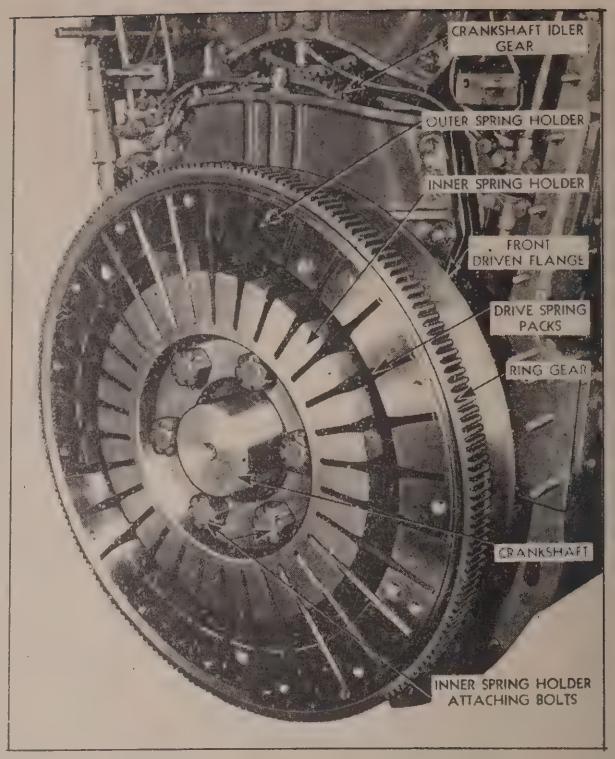


Fig. 7F
Elastic Coupling—Outer Plate Removed

Remove Elastic Coupling.

1. Remove generator.
2. Remove elastic coupling upper housing. Turning gear assembly will come off with housing.
3. Remove lower elastic coupling housing.
4. Remove camshaft drive housing cover. (See Section K.)
5. Remove lower camshaft drive housing.
6. Remove side sections of lower camshaft drive housing.

7. Dismount all rocker levers.
8. Remove oil slinger.
9. Remove lockwire and capscrews on outer drive flange.
10. Remove capscrews and remove dowel lock plates.
11. Pull dowels holding outer drive flange to other spring holder by stacking flat washers having an inside diameter larger than diameter of dowel and inserting capscrew through washers into dowel and tightening.

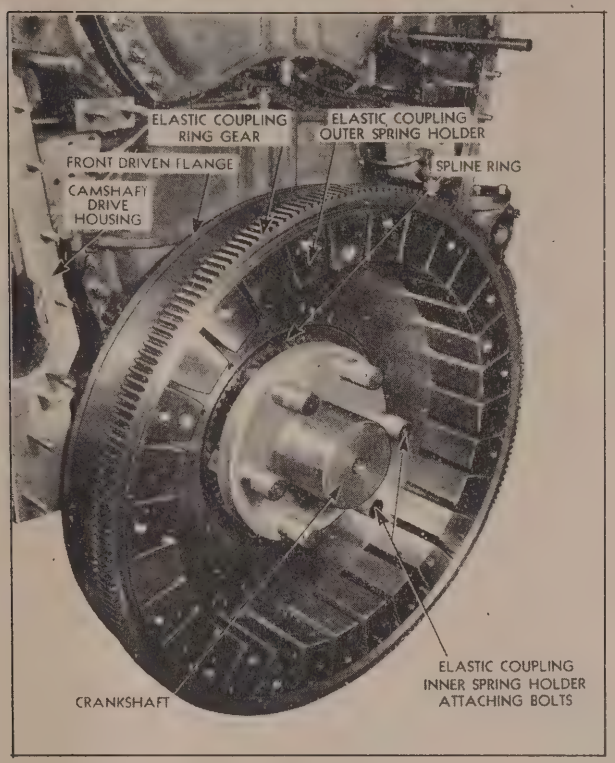


Fig. 8F
Elastic Coupling—Outer Plate Removed

12. Remove outer drive flange.
13. Remove camshaft idler gear and bearing support assembly. (See Section K.)
14. Pull out spring packs. Spring packs must be kept separate from each other and kept free from dirt and grit.
15. Remove cotter pins and nuts holding inner spring holder to crankshaft.
16. Insert 2 jackscrews in holes in inner spring holder and tighten until spring holder can be lifted off crankshaft.
17. Remove castellated nuts, capscrews and lock plates holding front driven flange to spline ring.

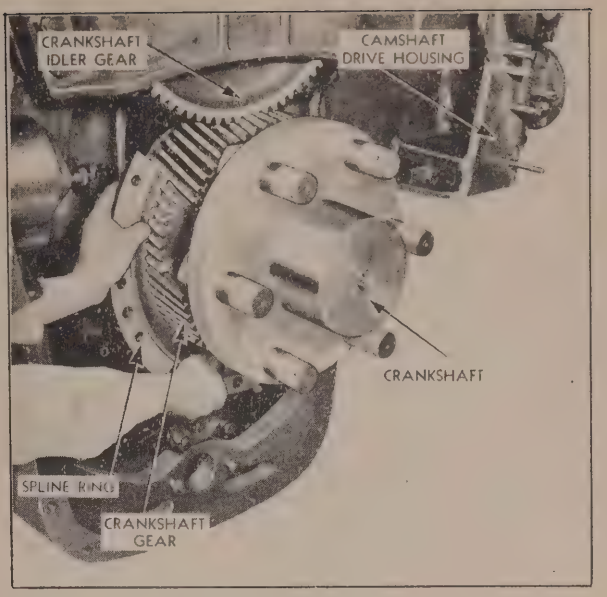


Fig. 9F
Removing Spline Ring

18. Attach hoist to front driven flange and outer spring holder. Pull dowel pins holding driven flange to spline ring. Remove outer spring holder and driven flange from spline ring.
19. Remove lubricating oil line from engine inlet to main lubricating oil manifold. (See Section P.)
20. Mark the spline ring spacers so they will be reassembled in the proper split-joint and remove spline ring studs. With split-joint horizontal,

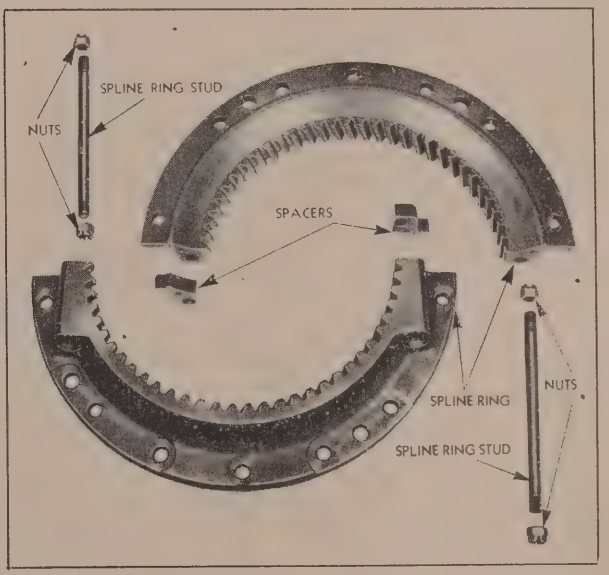


Fig. 10F
Spline Ring

slide lower half of spline ring toward front of engine until it is free of crankshaft gear.

21. Roll crankshaft gear over and remove other half of spline ring. (See Fig. 9F.)

Install Elastic Coupling.

1. Line up match-mark on crankshaft gear with the match-mark on the spline ring half. Slide ring over gear.
2. Check to be sure the match-markings line up.
3. Roll crankshaft gear over and slide other half of spline ring over gear.
4. Insert the spacers in their proper places and install spline ring studs. Tighten nuts and insert cotter pins.
5. Turn crankshaft gear until match-marks on crankshaft gear and idler gear line up.
6. Mark the inside of the gear with chalk so that location of match-mark can easily be seen when the elastic coupling inner flange is in place.
7. Attach hoist to inner flange and outer spring holder assembly and hoist into position. Roll crankshaft gear if necessary to align dowel holes and capscrew holes. The inner flange and spline ring will line up in only one position so be sure all holes line up.
8. Install capscrews and pull up only enough to pull assembly in place.
9. Insert dowels, dowel lock plates and tighten capscrews. Lockwire.
10. Install castellated nuts on dowels and insert cotter pins.
11. Line up etched marking "X" on inner spring holder and crankshaft flange and install inner spring holder.
12. Install nuts and tighten. Insert cotter pins.
13. Bring marked tooth, on inner spring holder, opposite marked tooth on outer spring holder.
14. Clean the springs in the spring packs, oil the springs lightly and reinstall.
15. Place outer drive flange in position and line up dowel and capscrew holes. The flange will fit in only one position.
16. Install dowels, dowel lock plates, and capscrews, tighten and lockwire.
17. Balance of assembly is reverse of disassembly.

MAIN BEARINGS

Description. Each main bearing consists of an upper and lower double flanged, precision bearing shell. Two types of main bearing shells are used. One type is bronze-backed with a centrifugally cast lining of a high-lead bearing metal containing a special hardener. The other type is steel-backed, with an intermediate lining of bronze, and lining of bearing metal.

The upper shell is mounted in the bearing cap and the lower shell in the main bearing seat, which is bolted to the cylinder block cross frame. The joint faces of the upper and lower bearing shells project a very small amount above the seat and cap. This is to insure that the backs of the shells will be forced into full contact when the cap is fully tightened. A drilled hole in the upper shell fits on a dowel pin in the cap. The dowel pin locates the upper shell in the bearing cap, and prevents both the upper and lower shells from rotatiug.

Each bearing shell is marked on the edge of one flange. For example, 2-L-B.E. indicates that the shell so marked is for the number **2** main bearing, the **L**ower bearing shell, and the flange so marked must be toward the **B**lower **E**nd of the engine. The main bearing nearest the blower end of the engine is the number one main bearing. Upper and lower bearing shells are not interchangeable.

Crankshaft thrust loads are taken by the rear main bearing. The thrust bearing shells are the same as the other main bearing shells except that the bearing metal is extended to cover the flanges.

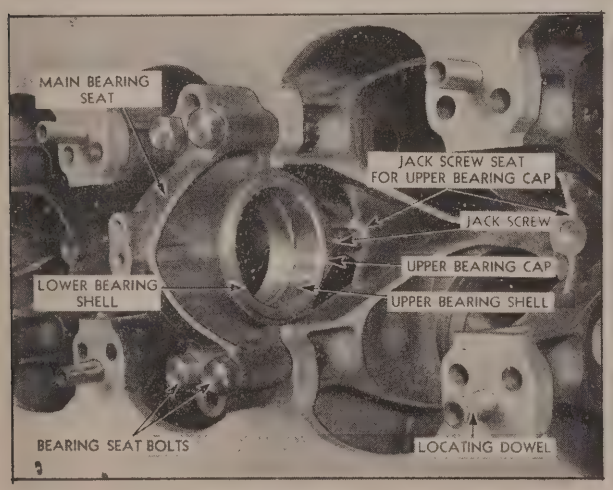


Fig. 1G
Main Bearing Assembly

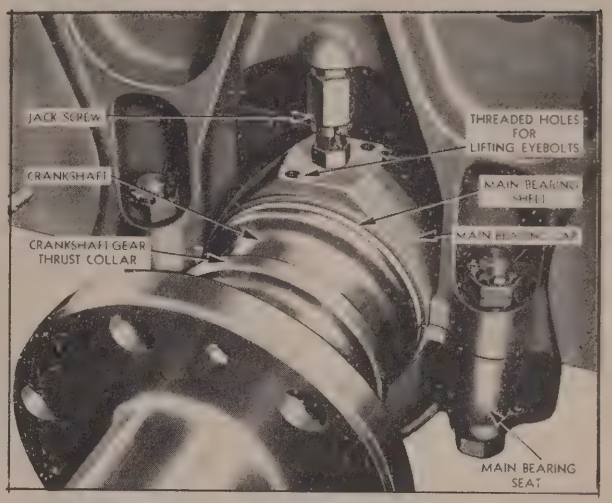


Fig.2G
Main Bearing Cap Installed

Each main bearing cap is marked with its bearing number and is marked "Blower End" on the side that should face the blower end of the engine.

The bearing surface of the lower bearing shell has an oil groove starting from the joint face at each side and extending partially around the inner surface of the shell. The lubricating oil flows through holes drilled in each groove of the lower shell.

Each upper bearing shell is grooved midway between the bearing flanges. The lubricating oil flows from the partial groove in the lower shell to the upper shell groove.

Maintenance. Misalignment of the crankshaft may occur if one bearing should wear more than another one. If the shell wears to the extent that all the lining is worn off, the bearing may seize and cause serious damage to the engine. Therefore, the main bearing shells should be removed and inspected after every 2000 to 2500 hours of engine operation.

Since these are precision bearing shells, new shells should not be filed or scraped. The clearance between the main bearing shells and the crankshaft journal, when the shells are new, is given in Section C.

Main Bearing Shell Inspection (Bronze-backed Shells). The bearing shell thickness may be measured using a micrometer in conjunction with a steel ball. When either the upper or lower bearing

shell has worn so that it is less than 0.355″ in thickness, both shells must be renewed.

Main Bearing Shell Inspection (Steel-backed Shells). When the intermediate bronze lining starts to show through the bearing metal of either the upper or lower bearing shells, both shells must be renewed.

Remove Main Bearing Shells with Crankshaft in Place.

Note: Do not remove more than one main bearing at a time.

1. Remove crankcase handhole covers, adjacent to main bearing shell to be removed, by loosening handwheels in center of covers, pulling covers out and turning sideways, to clear clamp.
2. Remove jackscrew.
3. Lift main bearing cap off dowels. Care must be taken not to damage shell when removing cap.

   Note: It may be necessary to insert eyebolts in the tapped holes for ease in handling.
4. Using special tool roll lower shell from its seat by turning crankshaft.

Replace Main Bearing Shells.

Note: If new shells are to be installed they must be marked before installation so that they can be returned to their original locations after later removal. Upper and lower bearing shells are not interchangeable.

1. Clean lower shell and oil with clean engine oil.

Fig. 3G
Installing Main Bearing Shell

2. Roll shell into its seat. (See Fig. 3G.) Shell is marked for blower end.
3. Clean and oil upper shell. Shell is marked for blower end. Place in bearing cap.
4. Replace bearing cap and jackscrew. Cap is marked for blower end. Tighten jackscrew until the match-marked faces on the screw head and body are aligned. Insert new cotter pin.

PISTONS, CONNECTING RODS, AND CYLINDER LINERS

Pistons

The piston is made of alloy cast iron. The bored holes in the piston-pin hubs are fitted with bronze bushings. The outer ends of the bore for the full-floating alloy steel piston pin are sealed with cast iron caps.

A cooling-oil chamber is formed by an integral baffle under the piston crown. Lubricating oil under pressure flows from the top of the connecting rod, through a sealing member, and into the cooling chamber. The oil seal is a spring loaded shoe which rides on the cylindrical top of the connecting rod. The heated oil overflows through two drain passages.

Each piston is fitted with seven cast iron rings, five compression rings above the piston pin and two oil-control rings below. These rings are of the conventional one-piece, cut-joint type.

For the piston clearances in the cylinder bore, see Section C.

Maintenance. After cleaning the piston thoroughly with carbon tetrachloride or similar cleaner the piston skirt, ring grooves, and rings should be inspected for cracks, chipped surfaces or scores. Any defective parts should be renewed.

The piston can be inspected for stuck rings by removing the air box handhole covers and pressing on the rings with a pointed stick. If any of the rings are not free, remove the piston and soak it in a 30% solution of No. 9 Oakite and 70% kerosene for twenty-four hours. This will enable the piston rings to be removed without resorting to scraping. Remove the piston rings and clean the piston and ring grooves with water or steam if available. Renew the stuck piston rings.

The clearance on diameters between the piston and the liner should be checked with micrometers by measuring the outside piston diameters and the inside liner diameters. These clearances should be measured both on the line of the piston pin and at right angles to it. The clearances should be checked in three places—between the bottom two compression rings, and at the top and bottom of the piston skirt. Clearances must be kept within the limits specified in Fig. 10H. When the outside diameter of the piston skirt has worn to 8.722" or less the piston should be renewed.

In manufacture the bushings are shrunk into the piston by a special refrigerating process which reduces the bushing to a temperature lower than that which can be obtained by the use of dry ice. After the bushings are installed in the piston they are line bored to the correct inside diameter.

When the bushings in the piston are worn so that the inside diameter measures 3.0085" or more a new piston should be installed.

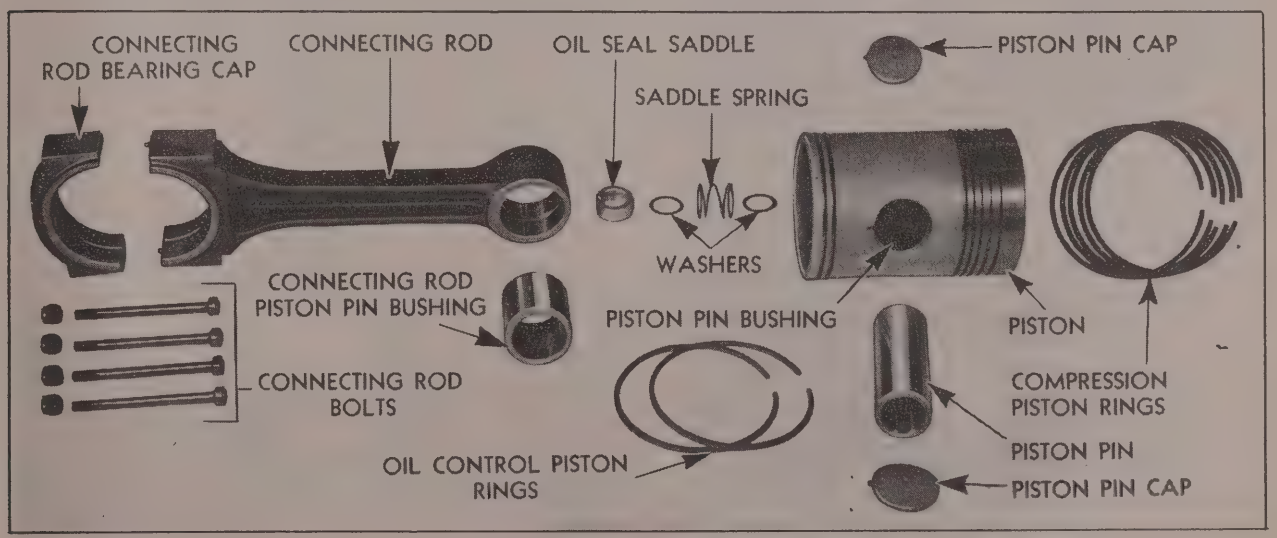


Fig. 1H
Piston and Connecting Rod Disassembled

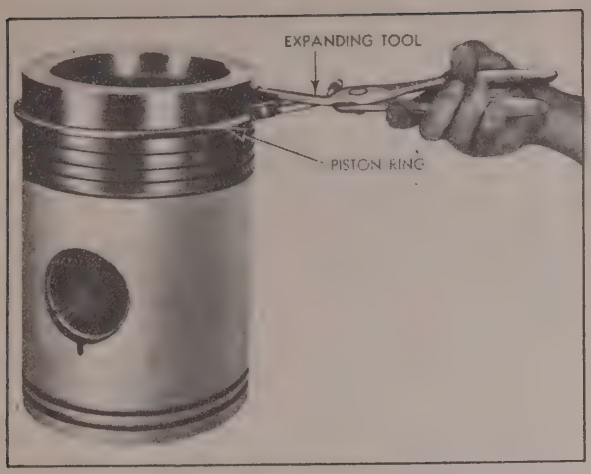


Fig. 2H
Removing Piston Rings with Expanding Tool

A ring assembly tool is furnished with the engine for replacing the rings in the piston grooves and for removing them from the grooves. This special ring expander is fitted with an adjustable stop which limits the maximum opening of the jaws and the resulting expansion of the rings. This stop should set so that the rings will be expanded only enough to clear the outside diameter of the piston. An excessive expansion of the rings may lead to early failure in service. (See Fig. 2H.)

When replacing the piston in the cylinder, the piston ring guide, which is furnished with the engine, should be used. The tapered bore in this sleeve compresses the piston rings and guides them into the cylinder bore. Before the rings enter the guide the ring gaps should be staggered by placing them to face alternately toward the power take-off end and toward the blower end of the engine. (See Fig. 10H.)

Connecting Rods

See Figs. 3H and 4H

Description. The connecting rod is an alloy steel forging. The connecting rod bearing in the lower end of the connecting rod consists of upper and lower bearing shells. Two types of connecting rod bearing shells are used in the series 278A engines. One type is bronze-backed with a centrifugally cast lining of a high-lead bearing metal containing a special hardener. The other type is steel-backed, with an intermediate lining of bronze, and an inner lining of bearing metal. Each connecting rod bearing shell is marked on the edge of one flange. For example, 2-L-B.E. indicates that the shell so marked is for the number **2** connecting rod, the **L**ower bearing shell, and the flange so marked must be toward the **B**lower **E**nd of the engine. 10-U-G.E. indicates the shell is for the number **10** connecting rod, the **U**pper bearing shell and the flange so marked must be toward the **G**enerator **E**nd of the engine. No shims are used between the connecting rod and the bearing cap. *Upper and lower bearing shells are not interchangeable.*

The lower shell is mounted in the bearing cap and the upper shell in its seat in the connecting rod. The joint faces between the upper and lower shells project a very small amount above the seat and cap. This is to insure that the backs of the shells will be forced into full contact when the cap is fully tightened. A slot in the back of the lower shell fits on a dowel pin in the cap. The dowel pin locates the

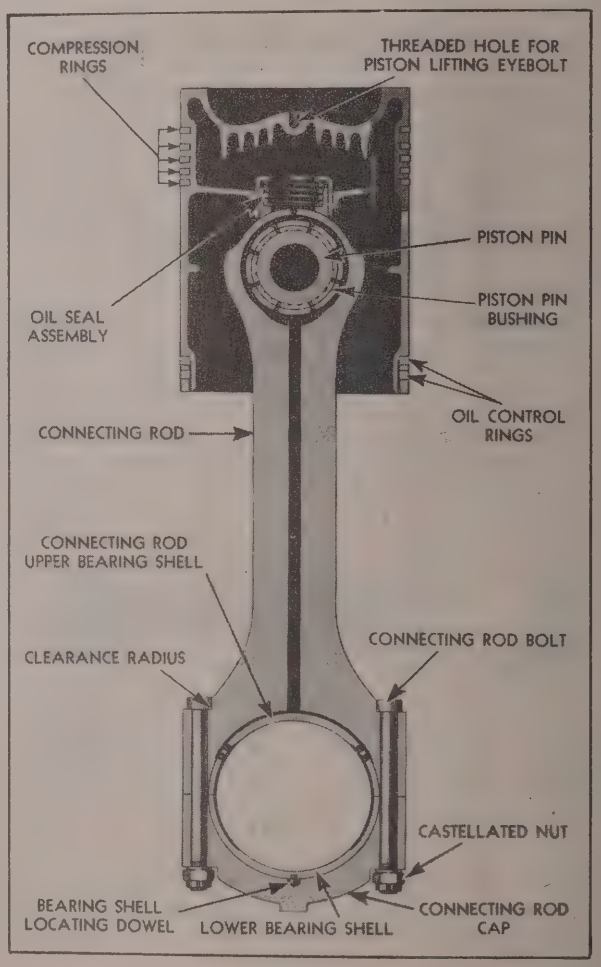


Fig. 3H
Piston and Connecting Rod Assembly

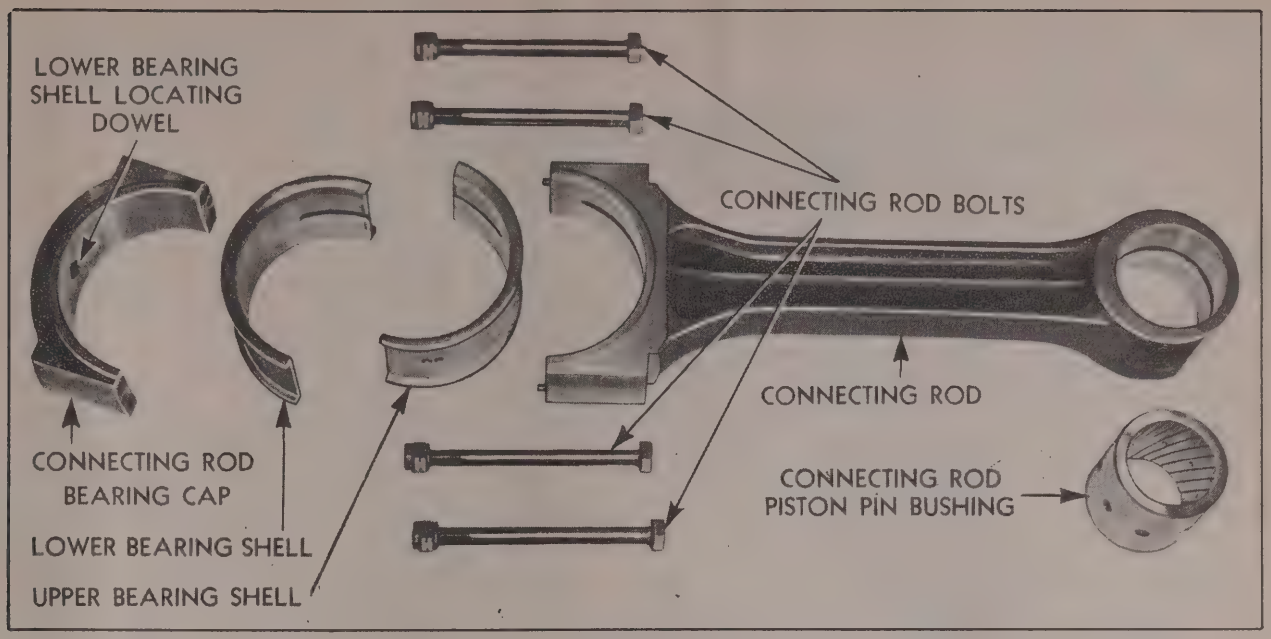


Fig. 4H
Connecting Rod Assembly

lower shell in the connecting rod cap and prevents both the upper and lower shells from rotating.

The piston pin is of the full floating type. The bronze steel-backed bushing floats in the upper hub of the connecting rod. The ends of the pin oscillate in the bronze bushings in the piston.

Lubrication and Cooling. The crankpin bearing is lubricated with oil received from an adjacent main bearing, through oil passages in the crankshaft. Oil holes in the upper bearing shell and drilled passages in the connecting rod conduct lubricating oil to the piston-pin end of the rod. The oil flows through a hole in the top of the rod and into the piston cooling chamber.

The bearing surface of the upper and lower bearing shells have oil grooves starting from the joint face at each side and extending partially around the inner surface of the shells.

A bronze oil seal saddle rides on the machined top of the connecting rod and is held against the connecting rod by a spring. There is a washer between the spring and the oil seal guide, and also between the spring and the oil seal saddle.

Maintenance. The floating piston pin bushing in the connecting rod should be renewed when the inside diameter measures 3.0115″ or more or when the outside diameter measures 3.864″ or less. The piston pin should be renewed if the diameter is less than 2.992″.

The connecting rod bearing shells should be removed and inspected after every 2000 to 2500 hours of engine operation. These are precision bearing

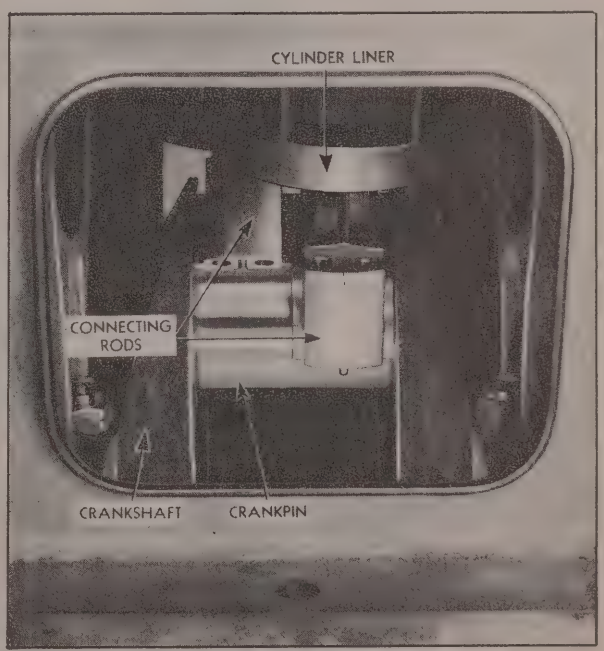


Fig. 5H
Position of Connecting Rods on Crankshaft

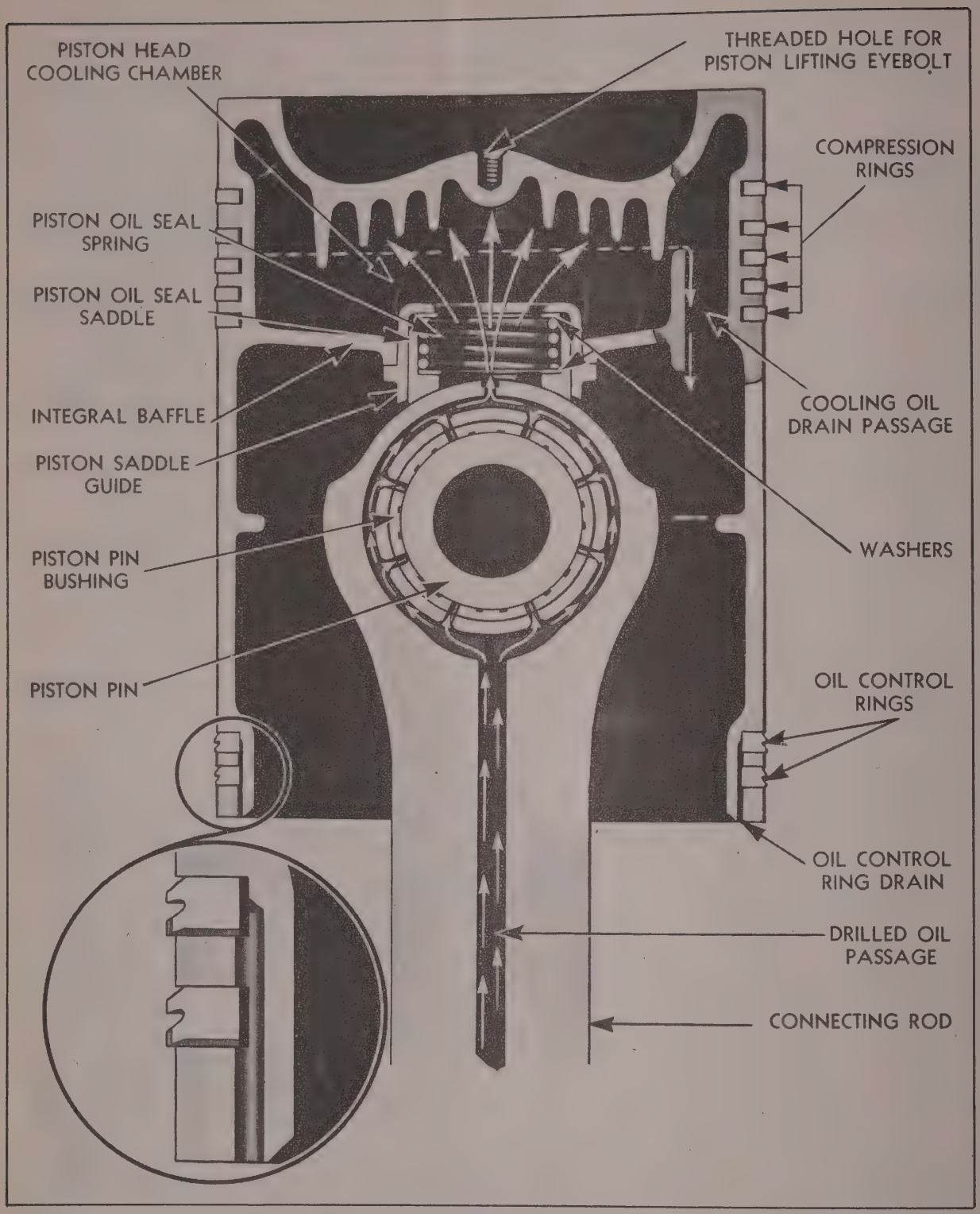


Fig. 6H
Lubrication and Cooling of Piston

shells and should not be filed or scraped. The required clearance between new connecting rod bearing shells and the crankshaft journal is given in Section C.

Connecting Rod Bearing Shell Inspection (Bronze-backed Shells). When either the upper or lower bearing shell has worn so that it is less than 0.238″ thick or if the bearing shells are badly scored or the bronze backing cracked, both shells must be renewed.

Connecting Rod Bearing Shell Inspection (Steel-backed Shells). When the intermediate bronze lining starts to show through the bearing metal of either the upper or lower bearing shells, or if the bearing shells are badly scored both shells must be renewed.

Remove Piston and Connecting Rod.

1. Drain fresh water system.
2. Remove cylinder head. (See Section J.)
3. The carbon should always be scraped from the cylinder liner before attempting to remove piston.

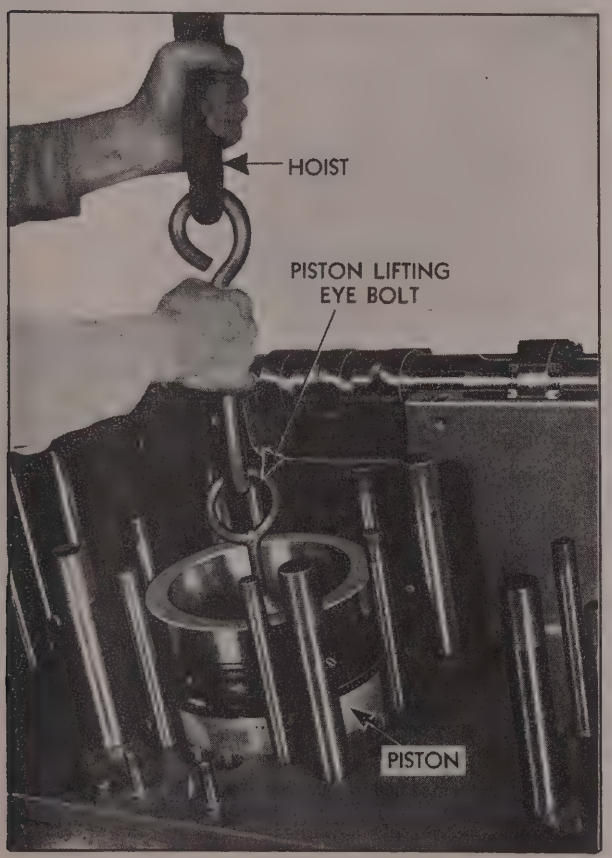


Fig. 7H
Removing Piston from Engine

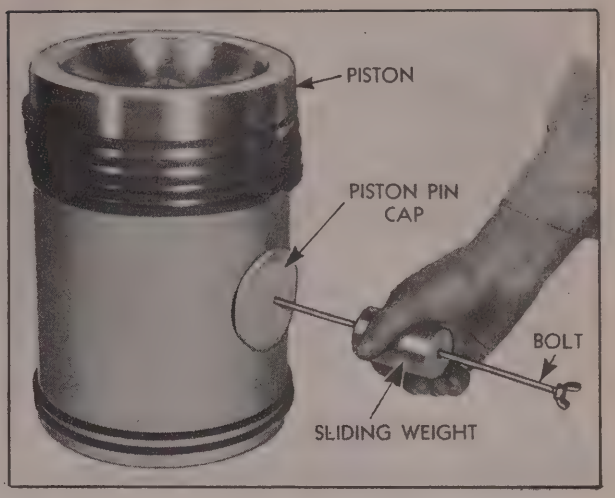


Fig. 8H
Removing Piston Pin Cap

4. Remove crankcase handhole covers on both sides, by loosening the handwheel, pulling cover out, and turning sideways to clear inner clamp.
5. Open cylinder test valves in all other cylinder heads and turn crankshaft so that piston being removed is at approximately top dead center.
6. Loosen castellated nuts on lower end of connecting rod. Drive bearing cap off dowels evenly with babbitt hammer.
7. Remove nuts and bearing cap. Be careful that the bearing shell does not fall out of cap. Remove connecting rod bolts.
8. Screw piston lifting eyebolt into hole in top of piston as shown in Fig. 7H. After lifting piston slightly check upper bearing shell to see that it is tight in its seat. If loose, it should be removed before lifting piston farther. Care should be taken to lift along the axis of the cylinder liner, and to see that connecting rod does not score liner wall. Do not allow rod to swing and strike piston skirt as this may damage piston. Replace bearing shells, cap and bolts in rod, to prevent damage to bearing shells.

Disassembling Piston and Connecting Rod Assembly.

1. Stand assembly on piston crown.

2. Remove one piston pin retaining cap. This can be done by using a long threaded rod and a steel block with a hole larger than the rod diameter as shown in Fig. 8H.
3. Push down on connecting rod, and pull out piston pin. Remove connecting rod.
4. Push connecting rod bushing from connecting rod.
5. Remove saddle, spring and washers from piston. If it is desired to remove the piston rings this may be done with the special tool. Do not expand the rings more than is necessary to clear the piston. (See Fig. 2H.)

Assembling Piston and Connecting Rod.

1. Clean all parts and inspect for cracks, wear, or other damage. Renew all worn or damaged parts.
2. Oil parts before assembling.
3. Install piston rings.
4. Install bushing in connecting rod.
5. Stand piston on piston crown and insert oil saddle assembly. Be sure there is a washer at both ends of the spring.
6. Insert rod so that number on rod is on same side of assembly as number on piston. New pistons and connecting rods should be marked.
7. Push down on rod until rod bushing and piston bushings are in line. Then insert piston pin.
8. Replace piston pin caps by driving in place with block of wood. Be sure locating pin lines up with slot in piston.

Replace Piston and Connecting Rod in Engine.

Note: If new shells are to be installed they must be marked before installation so that they can be returned to their original locations after later removals. *Upper and lower bearing shells are not interchangeable.*

1. Screw eye-bolt into top of piston. Wipe off piston, connecting rod bearing, and crankpin. Lubricate crankpin, liner, connecting rod bearing, and piston. Make sure there is sufficient oil supply in back of each ring and stagger gaps fore and aft.
2. Install ring guide in top of liner and oil inner surface, Fig. 9H. Turn crankshaft until crankpin is at top dead center. With bearing cap removed, lower piston assembly carefully in liner. Cylinder numbers on piston and connecting rod must face left side of engine. The side of the connecting rods marked G.E. should face the power take-off end of the engine. The side of the rods marked B.E. should face the blower end of the engine. Use care to avoid scratching liner with connecting rod. Pay particular attention to each ring as it enters ring guide. Remove piston eyebolt.

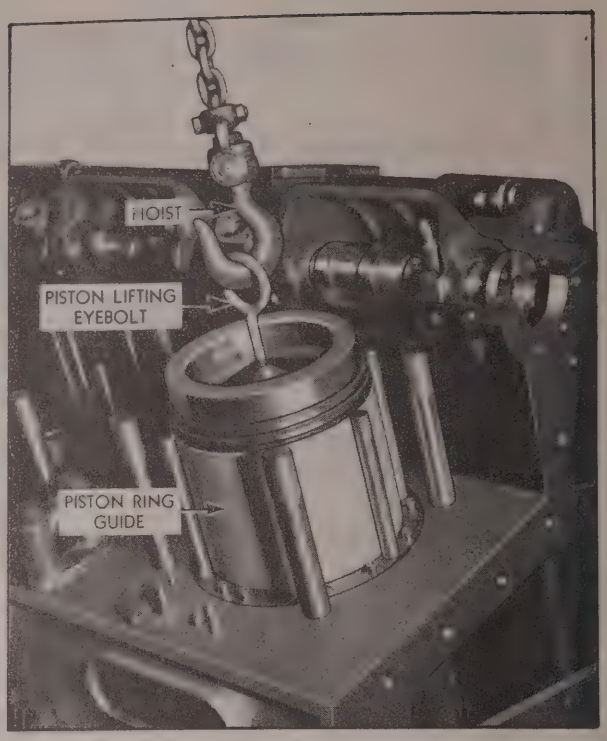


Fig. 9H
Installing Piston in Engine

3. Install connecting rod bolts and lower bearing shell and cap with markings matched. Be sure connecting rod bolt heads are in proper position with clearance radius as shown in Fig. 3H. Tighten nuts, and insert cotter pins.

Cylinder Liner

Description. The cylinder liner is a cylindrical alloy iron casting with cored annular spaces between the inner and outer surfaces through which cooling water is circulated. The liner is accurately bored to a smooth finish. The cylinder liner is held in the engine block by the lower deck plate and a recess in the upper deck plate, and is held securely to the head by six alloy steel studs and nuts. The lower deck plate has a groove which serves as the water

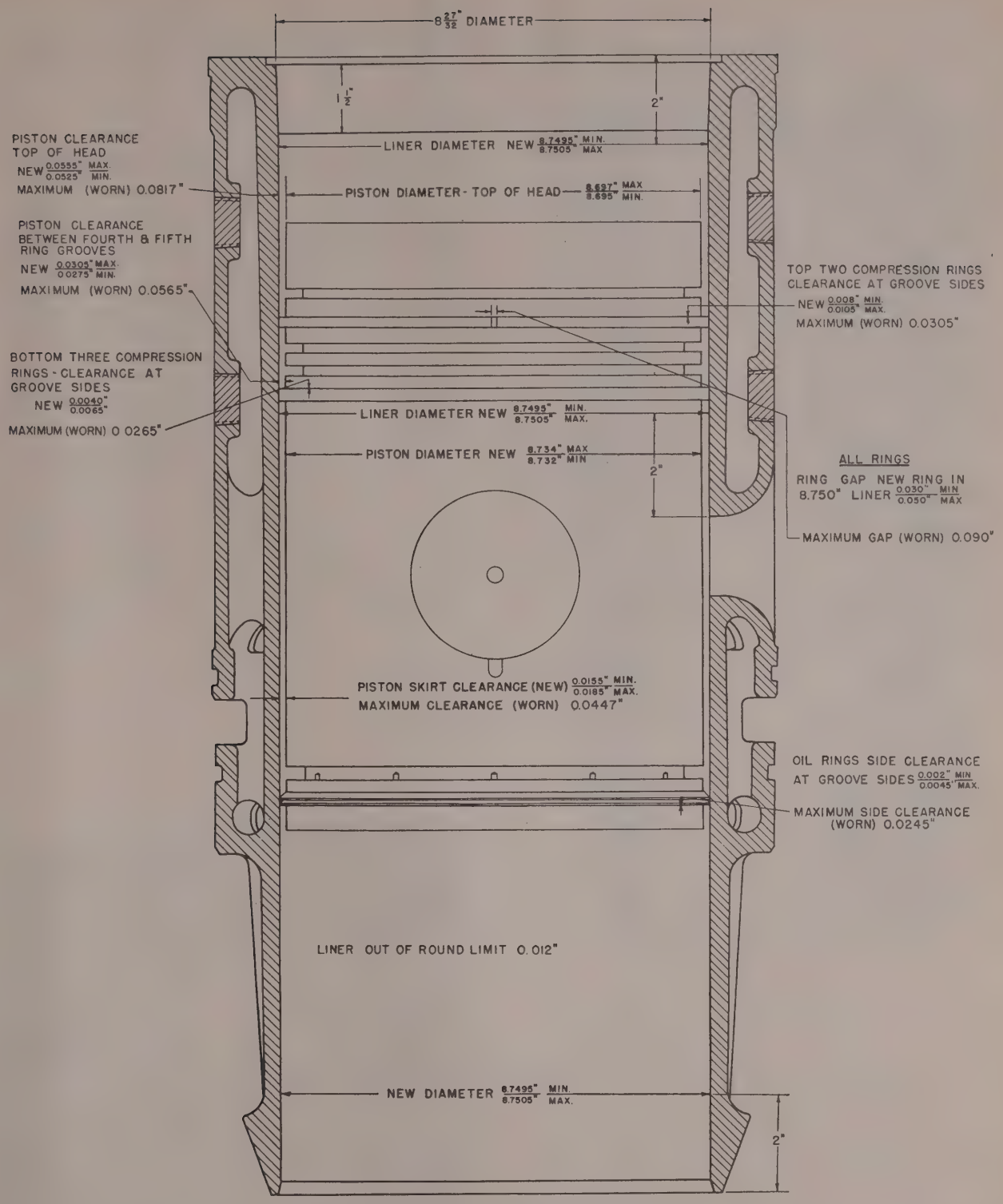

8 27/32" DIAMETER
1 1/2"
2"
PISTON CLEARANCE TOP OF HEAD
NEW 0.0555" MAX. 0.0525" MIN.
MAXIMUM (WORN) 0.0817"
LINER DIAMETER NEW 8.7495" MIN. 8.7505" MAX
PISTON DIAMETER - TOP OF HEAD — 8.697" MAX 8.695" MIN.
PISTON CLEARANCE BETWEEN FOURTH & FIFTH RING GROOVES
NEW 0.0305" MAX. 0.0275" MIN.
MAXIMUM (WORN) 0.0565"
TOP TWO COMPRESSION RINGS CLEARANCE AT GROOVE SIDES
NEW 0.008" MIN. 0.0105" MAX.
MAXIMUM (WORN) 0.0305"
BOTTOM THREE COMPRESSION RINGS - CLEARANCE AT GROOVE SIDES
NEW 0.0040" 0.0065"
MAXIMUM (WORN) 0 0265"
LINER DIAMETER NEW 8.7495" MIN. 8.7505" MAX.
PISTON DIAMETER NEW 8.734" MAX 8.732" MIN
2"
ALL RINGS
RING GAP NEW RING IN 8.750" LINER 0.030" MIN 0.050" MAX
MAXIMUM GAP (WORN) 0.090"
PISTON SKIRT CLEARANCE (NEW) 0.0155" MIN. 0.0185" MAX.
MAXIMUM CLEARANCE (WORN) 0.0447"
OIL RINGS SIDE CLEARANCE AT GROOVE SIDES 0.002" MIN 0.0045" MAX.
MAXIMUM SIDE CLEARANCE (WORN) 0.0245"
LINER OUT OF ROUND LIMIT 0.012"
NEW DIAMETER 8.7495" MIN. 8.7505" MAX.
2"

Fig. 10H
Cylinder Liner Wear Limits

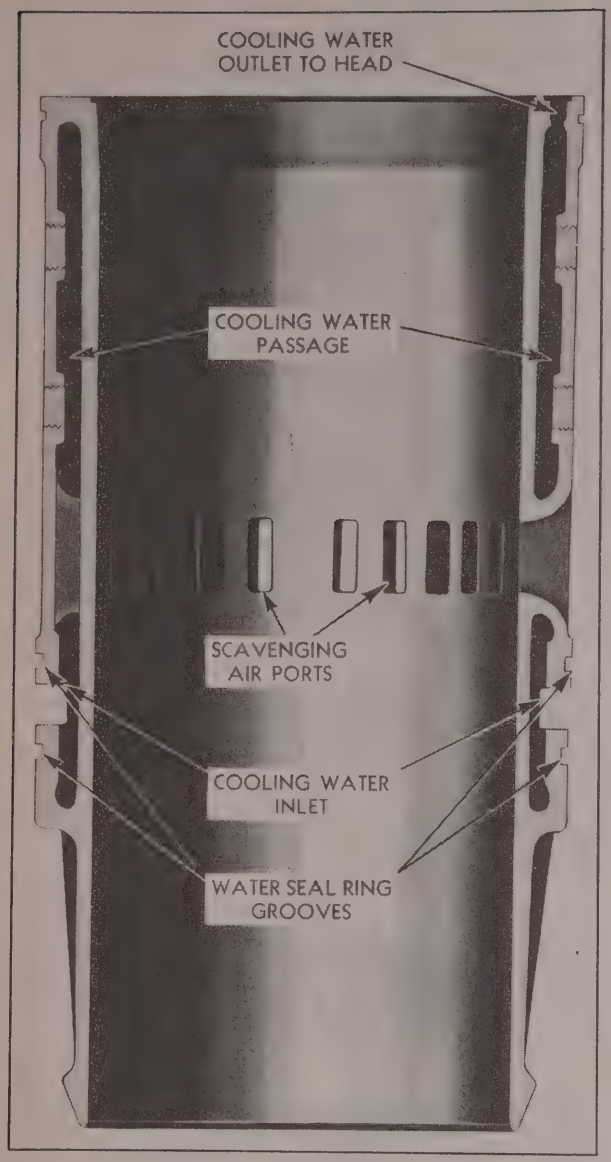


Fig. 11H
Cylinder Liner

inlet into the passages in the cylinder liner. It is made water-tight by two synthetic rubber ring gaskets. The cooling water flows up through the cylinder liner and into the cylinder head through ferrules made water-tight by synthetic rubber gaskets. The air intake ports through which scavenging air from the blower enters to supply the cylinder with fresh clean air, are located around the circumference of the liner. When the piston reaches the bottom of its stroke the ports in the side of the liner are completely open and the air space above the piston is charged with fresh air.

The joint between the cylinder liner and the cylinder head is made gas tight by a copper gasket that fits on a shoulder at the top of the cylinder liner.

Maintenance. Water tight seals are formed around the ferrules in the top of the liner by small synthetic rubber ring gaskets. These gaskets should be installed new each time a cylinder head is removed from the engine. The synthetic rubber ring gaskets which form the seal at the top and bottom of the cooling water inlet holes around the circumference of the liner, should be renewed each time the liner is removed from the cylinder block.

The air box around the liner should be cleaned periodically through the handhole covers on the side of the engine block. When this cleaning is done care should be taken not to drop any dirt through the liner scavenging air ports into the cylinder.

The inside surface of the liner should be inspected for scoring. This inspection can be made through the air intake ports. Turn the crankshaft until piston is at the bottom of its stroke and inspect liner walls. If scoring is present the liner should be renewed.

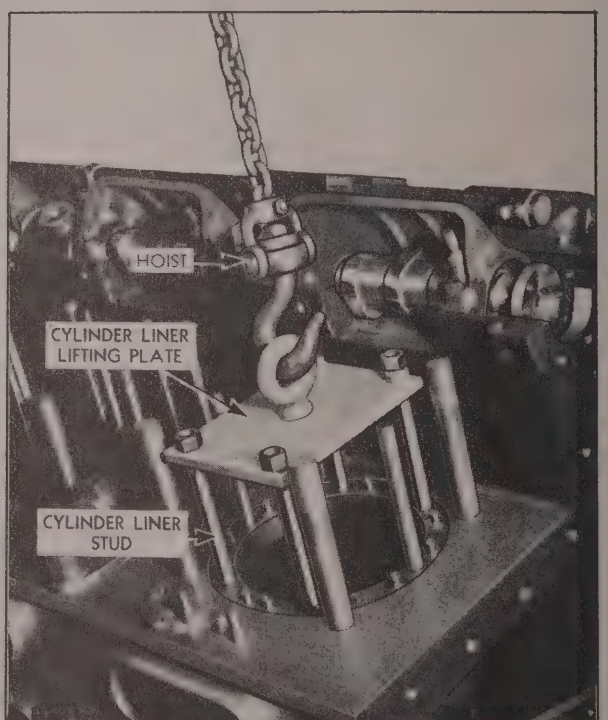


Fig. 12H
Removing Cylinder Liner from Block

The cylinder liner diameter should be checked with the piston and maintained within the limits given in Fig. 10H. When the inside diameter of the liner has worn to 8.777″ or more it should be renewed. When the liner is more than 0.012″ out of round, it should be renewed.

Remove Cylinder Liner.

1. Drain water.
2. Remove cylinder head. (See Section J.)
3. Remove piston and connecting rod assembly. (See page H-5.)
4. Remove copper gasket at top of liner.
5. Attach cylinder liner lifting tool to cylinder liner studs. Be sure crankpin is in bottom position. (See Fig. 12H.)
6. Attach hoist and loosen liner by shaking before attempting to lift liner. Be sure to pull along the axis of the liner, otherwise liner will bind in block. It may be necessary to break liner loose with wood beam by prying at bottom of liner.
7. Lift liner out of block.
8. Remove both synthetic rubber seal rings.

To Replace Cylinder Liner.

1. With lifting tool in place, install new synthetic rubber seals on liner. Run smooth bar in back of each seal completely around liner to remove any twist in the seals. Grease exposed surfaces of seals.
2. Lower liner in block slowly, placing the longer liner studs nearest the campocket wall. Remove lifting tool.

CYLINDER HEADS

The engine cylinders are fitted with individual cylinder heads which are made of alloy cast iron.

Each cylinder head is fitted with four exhaust valves, the unit injector, the rocker lever assembly, an engine overspeed injector lock, the cylinder test and safety valves, and the air starter check valve in an air started engine. (See Section T.)

The cylinder head is located on the upper deck plate by dowels and is fastened to it with four hold-down studs. A vellumoid gasket between the head and the upper deck plate, two synthetic rubber seal rings over the inboard cylinder head studs, and a cork gasket around the injector micro-adjustment rod hole, seal the head. The joint between the head and the campocket wall is made oil tight with a synthetic rubber seal. The joint between the cylinder head and the cylinder liner is made gas tight with a copper gasket, and water tight with synthetic rubber grommets around each cylinder head to liner ferrule. Cooling water flows from the cylinder liner into the head and then flows into the water jacket of the exhaust elbow.

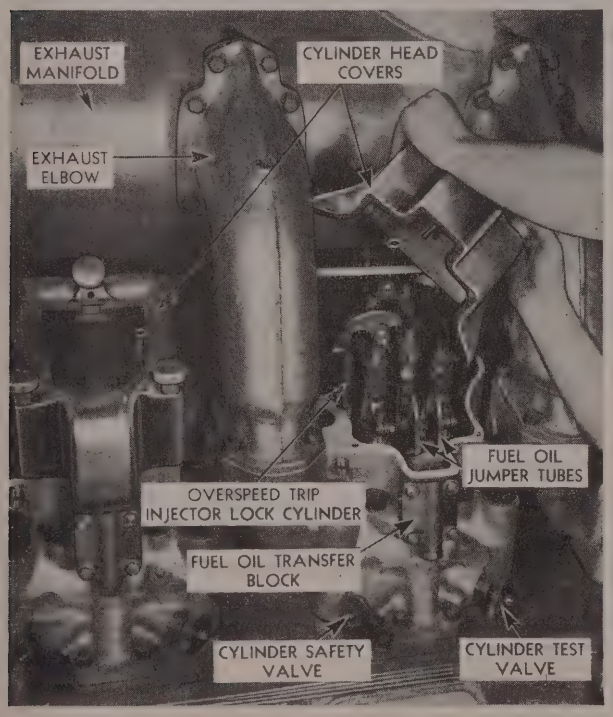


Fig. 1J
Removing Cylinder Head Cover

Remove Cylinder Head.

1. Drain fresh water system.
2. Close fuel supply valve. Loosen jet filter cap nuts in cylinder head to allow fuel to drain from jumper tubes.
3. Remove cylinder head cover.
4. Remove exhaust elbow.
5. Remove the rocker shaft lubricating oil line.
6. Remove cylinder head cover bracket.
7. Remove clevis pin from overspeed lock lever.
8. Remove nuts on rocker shaft bearing caps and lift off rocker levers, bearing caps, and shaft as an assembly.
9. Remove exhaust valve bridges, springs and seats.
10. Remove fuel oil jumper tubes.
11. Remove injector hold-down nut and clamp.
12. Remove injector. If injector sticks in cylinder head, the end of a suitable pinch bar may be inserted under one side of the injector body to pry injector loose. After removing injector, wrap carefully to protect spray tip. Lay aside where it will not be damaged.
13. Remove upper handhole cover, disconnect lower end of micro adjusting rod and remove rod.
14. Remove starting air line (if used) from distributor valve to cylinder head.
15. Disconnect overspeed trip line and fuel oil lines from head and fuel oil transfer block.
16. Remove cylinder head stud nuts and plain washers.
17. Remove cylinder liner stud nuts and plain washers.
18. Remove rocker lever shaft bracket using small pry bar. (See Fig. 4J.)
19. Remove nuts below fuel oil filter block holding head to block.
20. Screw cylinder head lifting eyebolt over injector hold down clamp stud and tighten.
21. Attach hoist to eyebolt and lift head from cylinder block. (See Fig. 3J.)
22. Remove seal rings from inboard cylinder head studs. Remove vellumoid head gasket, copper gasket from liner, and synthetic rubber water ferrule grommets.

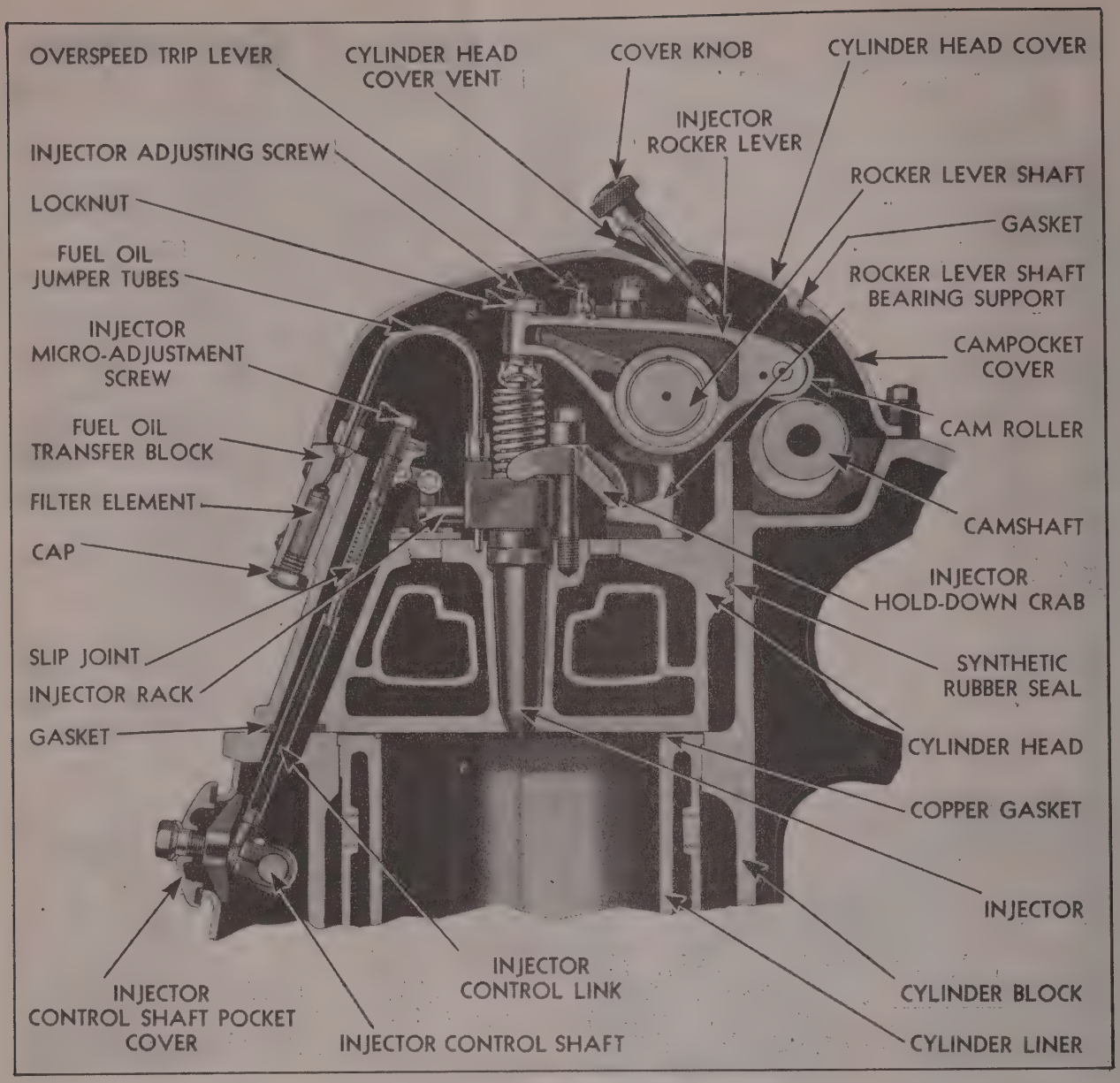


Fig. 2J
Cross Section of Cylinder Head through Injector

Installing Cylinder Head.

1. Be sure the copper ferrules on top of the liner are not damaged and place a new synthetic rubber grommet on each ferrule.
2. Clean upper deck plate and place vellumoid head gasket over cylinder head studs.
3. Place copper gasket on cylinder liner.
4. Place synthetic rubber seal rings over inboard cylinder head studs.
5. Cement synthetic rubber campocket wall seal to cylinder head. Grease outer surface of this seal and the campocket wall to let head slide down into place without disturbing seal.
6. Thoroughly clean bottom of head, top of piston, liner walls, etc. Blow out cylinder head passages with compressed air. Oil top of piston and liner walls.
7. Place cork gasket in cylinder head at micro adjustment rod hole.

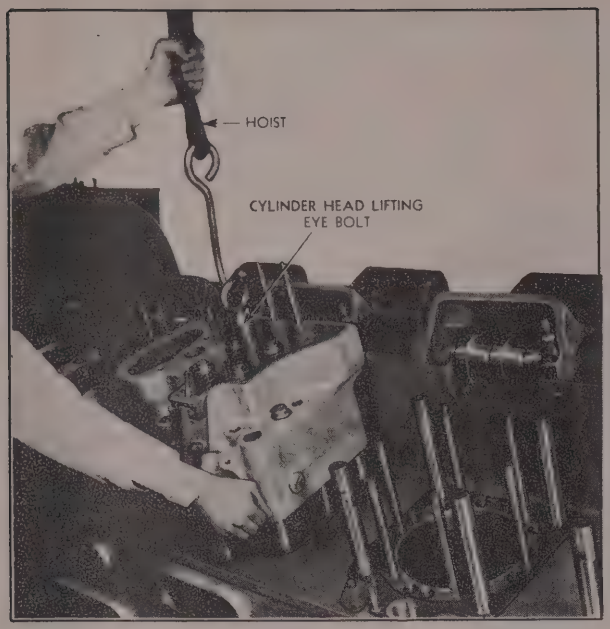


Fig. 3J
Removing Cylinder Head

8. Cover exhaust outlet hole in head, and plug injector hole from the top.
9. Line up liner so cylinder head will slide on studs evenly. (See "To Replace Cylinder Liner," Section H.)
10. Attach lifting eyebolt and chain hoist. Lower head over studs. Locate on upper deck plate dowels.
11. Place cylinder head flat washers and nuts and tighten evenly starting with the upper left corner moving to the lower right corner, then to the upper right hand corner, and finally the lower left corner. Tighten a small amount at a time until all of the nuts have been pulled down evenly to 500 foot pounds.
12. Install rocker lever support.
13. Place the cylinder liner stud washers and nuts and tighten in a definite order in diagonally opposite pairs. Assuming that the nuts are numbered consecutively from one to six around the circumference of the liner, the tightening order should be 1-4, 2-5, 3-6. Tighten a small amount at a time repeating the paired order until all of the nuts have been pulled down evenly to 175 foot pounds.
14. Install starting air line (if used) to cylinder head.
15. Install exhaust elbow.
16. Install injector micro adjustment rod. Be sure that the rod is free.
17. Install injector. (See Section N.)
18. Install fuel oil jumper tubes.
19. Install exhaust valve bridges.
20. Install rocker lever and shaft assembly. Be sure dowel in support fits in hole in shaft.
21. Install lubricating oil line to rocker lever shaft.
22. Install cylinder head cover bracket and cotter pin nuts.
23. Insert clevis pin in overspeed trip lever and install cotter pin.
24. Connect overspeed trip line and fuel oil lines to head and fuel oil transfer block.
25. Check gaskets, renew if damaged and install cylinder head cover.

Exhaust Valves

Description. The four exhaust valves are made of a special heat-resisting alloy steel. The valve stem guides are made of high test cast iron. They

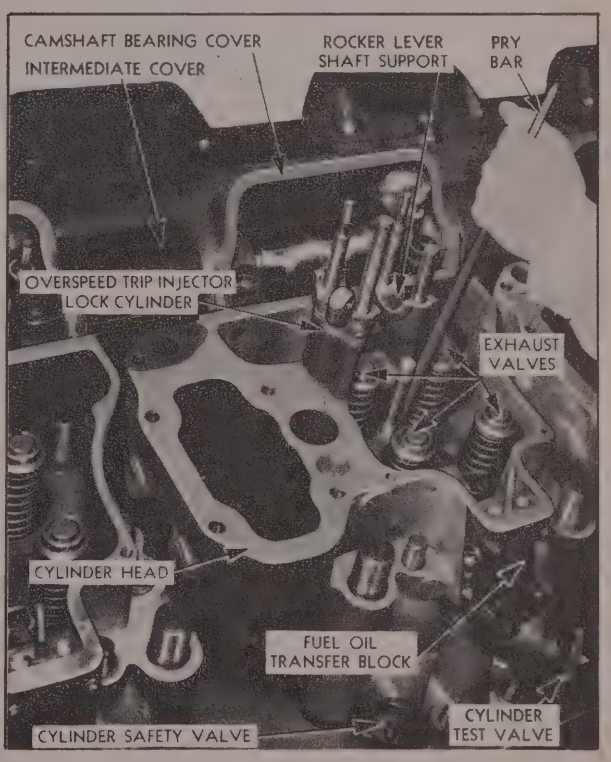


Fig. 4J
Removing Rocker Shaft Bracket

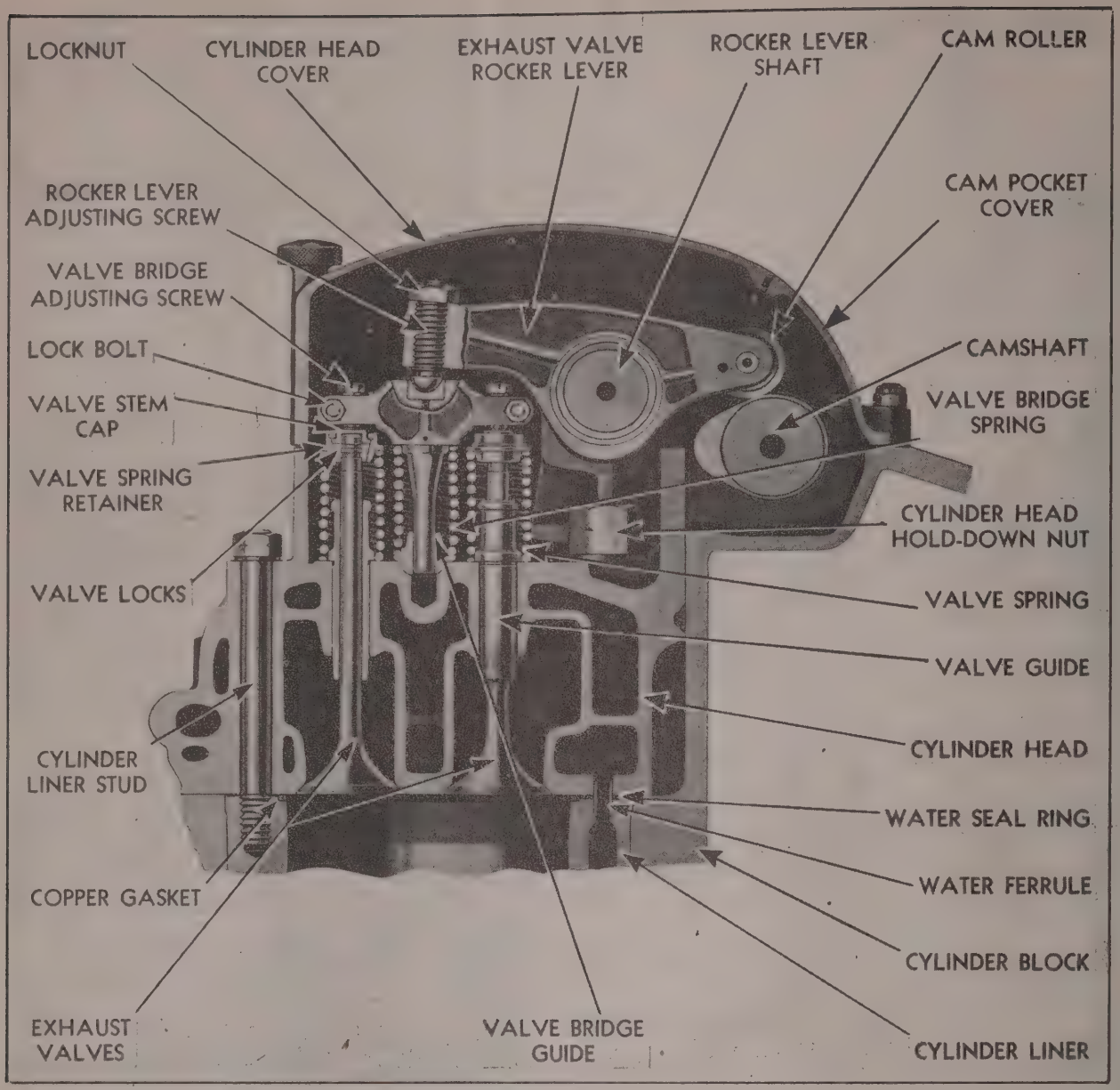


Fig. 5J
Cross Section of Cylinder Head through Valves

are pressed into the cylinder heads and then reamed for the fit to the valve stem.

Maintenance. The length of time the exhaust valves will run before they require overhauling depends upon several factors. The useful life of these valves will be shortened if overloads are carried or if the temperature of the discharged cooling water is allowed to run too high, because both of these conditions will cause burning of the valves.

It is good practice to overhaul the valves after not more than 3000 hours of actual running under full load and with good combustion. A valve reseating set is furnished for refinishing scored valve seats.

Before a valve spring is removed from any valve in a cylinder head that has not been removed from the engine, the piston in that cylinder should be placed in the top dead center position, so that the

valve will not drop into the cylinder when the valve stem is released from the spring seat lock.

Removing Exhaust Valves.

1. Remove cylinder head. (See page J-1.)
2. Remove snap ring holding valve spring cap and remove cap.
3. Using special valve spring compressing tool, (see Fig. 7J), compress valve spring and remove the two valve locks.
4. Remove spring seat and valve spring.
5. Perform the same operation on all four valve springs. Turn the head over and remove the valves.

Installing Exhaust Valves.

1. The installation of the exhaust valves is the reverse of the removal procedure.

Grinding Valves—Sioux Valve Grinding Set

Grinding Valve Seat.

1. Clean out valve stem guide hole with expanding cleaner. (See Fig. 8J.)
2. Place pilot stem in valve guide, see Fig. 9J. There are three sizes of pilots. Use largest size that will fit.
3. Slip seat grinding tool over pilot stem, see Fig. 9J. The angle of grinding tool should be checked and tool dressed before using. (See "Dressing Grinding Wheel.")
4. Attach motor to top of grinding tool and grind seat. (See Fig. 10J.)

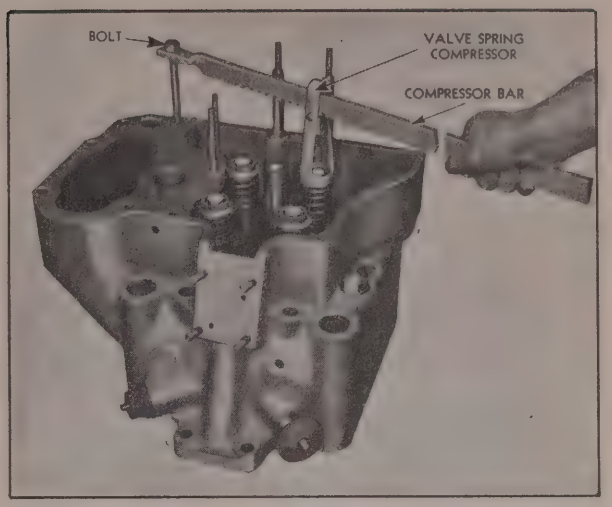


Fig. 7J
Removing Exhaust Valves

5. Slip dial indicator gauge over pilot and check seat for out-of-round, limit .0015". (See Fig. 11J.)

Grinding Valve.

1. Place grinding spring on valve stem and place valve in head. (See Fig. 14J.)
2. Apply lapping compound to seat and valve face.
3. Apply vacuum cup of hand grinding tool to top of valve and rotate crank until valve is sealed perfectly to seat. (See Fig. 15J.)

Dressing Grinding Wheel. (See Figs. 12J and 13J.)

1. Set tool at 45°.
2. Place grinding wheel and holder on mandrel.

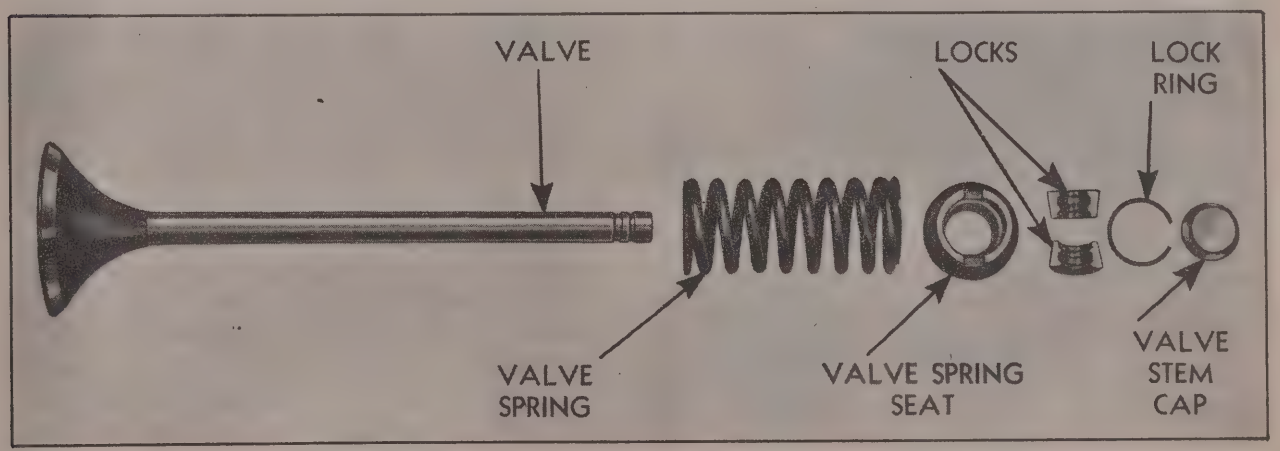


Fig. 6J
Exhaust Valve and Spring Assembly

3. Apply motor to holder and start.
4. Move dressing tool slowly up and down with lever. Do not take too large a cut as this will result in burning the diamond.

Rocker Lever Assembly

Description. Each cylinder head is equipped with three rocker levers, two of which operate the two pairs of exhaust valves, and the third operates the injector. The rocker levers are alloy steel forgings. Bushings are pressed into the lever hubs and are reamed for a bearing fit on the rocker lever shaft. The three rocker levers oscillate on a fixed shaft which is clamped in a bearing support. They are fitted with cam rollers, which operate in contact with the exhaust and injector cams. Each of the three cam rollers turns on a bushing and the bushing turns on a sleeve that has a loose mounting on the roller pin. Each of the valve rocker levers operates two valves through a bridge.

Each of the valve rocker levers is fitted at the valve end with a nut-locked adjusting screw, which has a hardened ball end that fits into the ball socket in the valve bridge. The injector rocker lever is fitted at the injector end with a nut-locked adjusting screw, which has a hardened ball socket at the lower end. The ball socket is fitted with a hardened steel shoe that is flexibily held to the adjusting screw. The shoe bears on the injector plunger follower and transmits the rocker lever motion to the injector plunger.

Fig. 8J
Cleaning Valve Guides

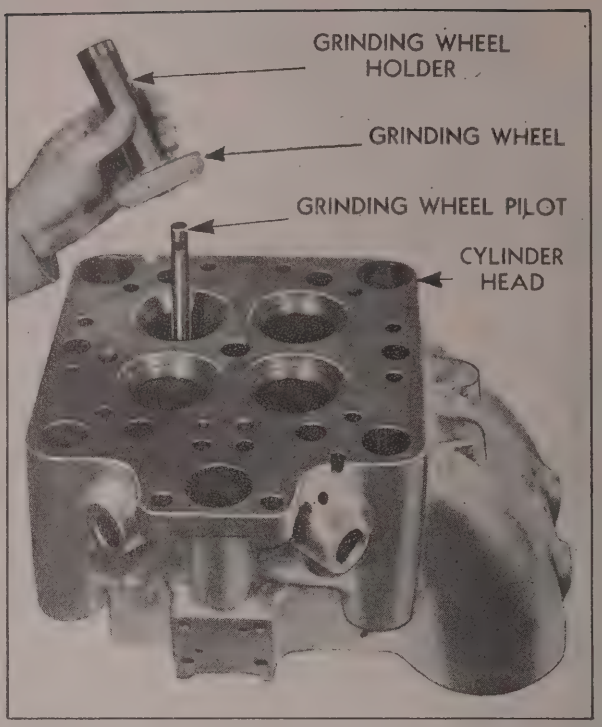


Fig. 9J
Placing Grinding Wheel on Pilot

The rocker lever shaft is made of alloy steel and it is ground to size. The shaft is clamped in the bearing support by two bearing caps, and is held in its correct location by a dowel pin in one of the bearings. A thrust plate is bolted to each end of the shaft, and a fiber gasket is placed in the joint between the thrust plate and the rocker lever shaft. The bearing support is positioned by two dowels and is held to the cylinder head by two of the cylinder liner studs. The injector hold-down clamp rests on the bearing support.

Each rocker lever assembly is lubricated with oil which is received from an adjacent camshaft bearing. The oil flows from the top of the camshaft bearing through a tube to the plate connection that is fastened to one end of the rocker lever shaft. From this connection, the oil flows through drilled passages in the rocker lever shaft to the three bearings in the rocker lever hubs.

A drilled passage in each of the rocker lever

forgings conducts the lubricating oil from a hole in the hub bushing to the camshaft end of the lever. The rocker lever motion permits oil to flow intermittently under pressure from the hole in the shaft, through one hole in the bushing and rocker lever to the cam roller. The bearing in each of the cam rollers receives oil through drilled holes in the roller pin and in the bearing bushings.

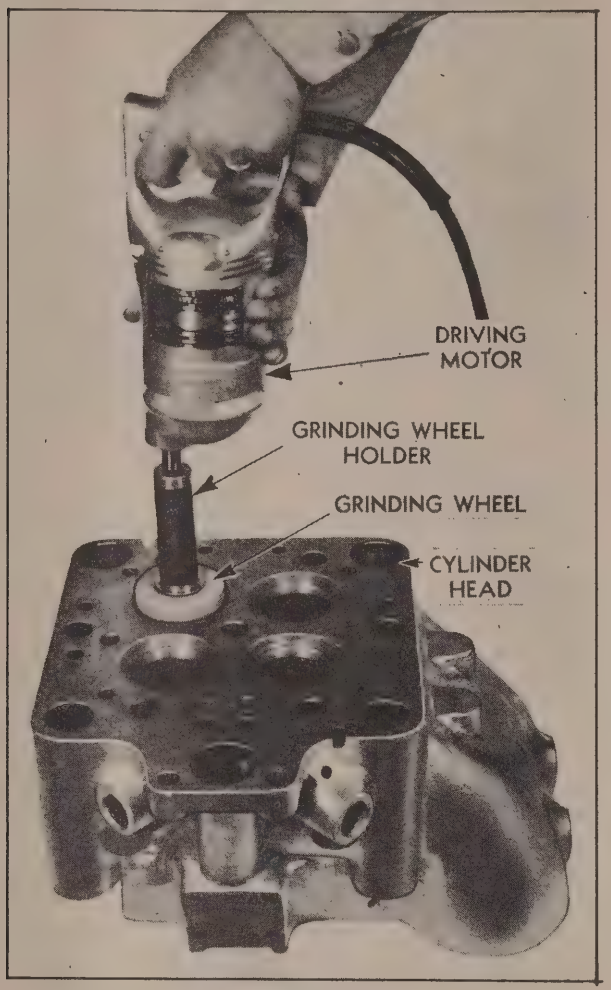


Fig. 10J
Grinding Valve Seat

Valve Bridges. Each forged steel valve bridge has a hardened ball socket into which the ball end of the valve rocker lever screw fits. The valve bridges are fitted with adjusting screws to equalize the valve clearances. (See Section E.) The lower part of the valve bridge is ground for a sliding fit in the guide which has a ball and socket bearing in the top of the cylinder head. The ball and socket bearings in the valve bridges are lubricated with spray that escapes from the rocker lever bearings.

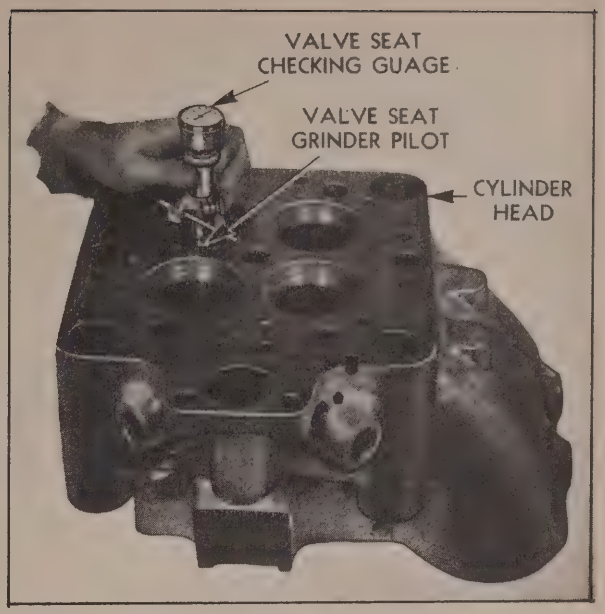


Fig. 11J
Checking Valve Seat

Remove Rocker Levers.

1. Remove cylinder head cover.
2. Remove lubricating line to rocker lever shaft.
3. Remove cylinder head cover bracket.
4. Remove overspeed trip cotter pin and clevis pin from overspeed trip lever.
5. Remove rocker shaft bearing cap nuts and lift out rocker lever bearing caps, shaft and rocker levers as an assembly.
6. Remove rocker lever shaft thrust plate and remove levers from shaft.

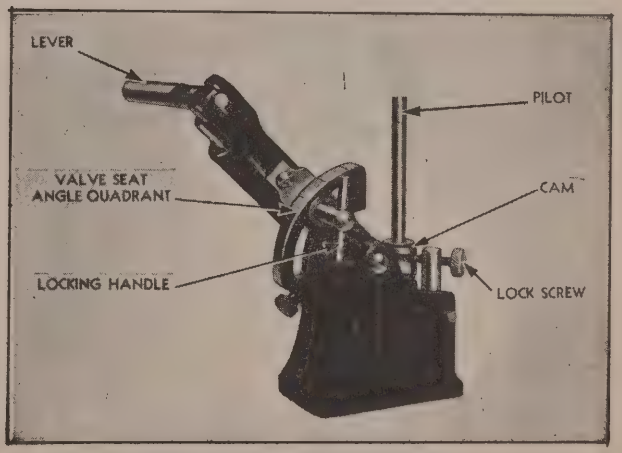


Fig. 12J
Grinding Wheel Dressing Tool

Assemble Rocker Levers and Shaft.

1. The assembly of the rocker levers and shaft is the reverse of the disassembly procedure. The rocker levers should be assembled on the shaft so that the two exhaust valve levers bend toward the injector lever. The dowel hole in the shaft should be between the injector lever and the left hand exhaust valve lever looking at the camshaft roller end of the levers.

Cylinder Test Valve

Description. Each cylinder head is equipped with a test valve which is used to vent the cylinder of any accumulated water and oil before starting, to relieve the cylinder compression when turning the engine over by hand, and to test compression and

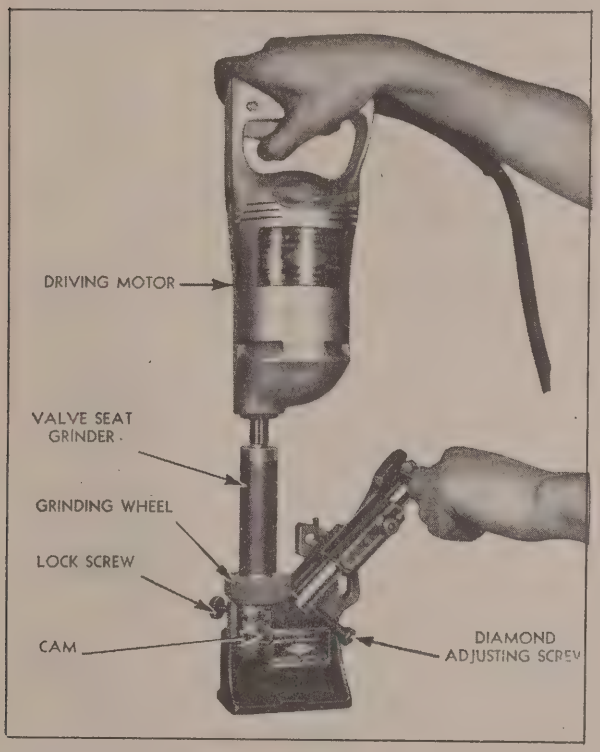


Fig. 13J
Dressing Grinding Wheel

firing pressures. The cylinder test valve is made up of a valve body, which is screwed into the cylinder head, and a valve stem, which has a threaded fit in the body and has a handwheel at the outer end. When the valve stem is screwed all the way out and the cylinder test valve is open, the secondary valve on the valve body is closed,

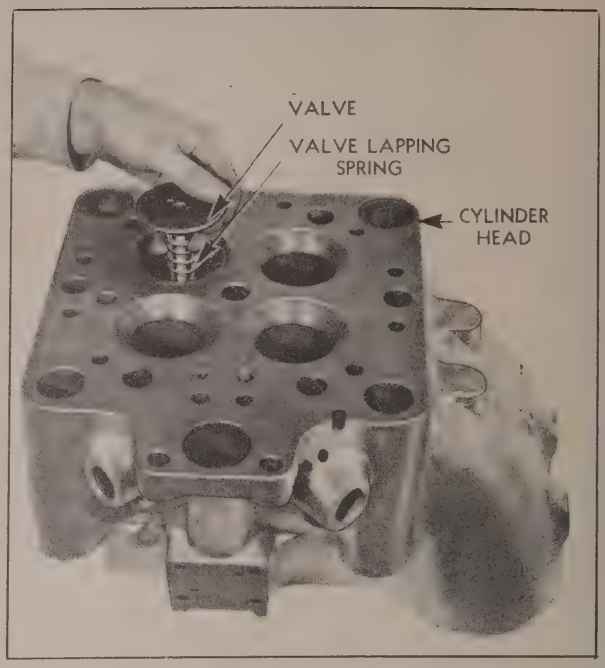


Fig. 14J
Placing Spring Under Valve Head

which prevents the passage of exhaust gases through the valve body. The cylinder test valves should be opened each time the engine is stopped.

Fig. 15J
Lapping Exhaust Valve

Maintenance. The cylinder test valves are in operation a comparatively small part of the running time and, consequently, do not require much attention. However, they should be kept tight at all times, otherwise, the escaping gases will score the valves and seats. A valve reseating tool is furnished for refacing the valve seat.

Removing Cylinder Test Valve.

1. Loosen locknut on valve body.
2. Unscrew valve body from cylinder head and pull out of head.

Installing Cylinder Test Valve.

1. Turn valve all the way out so that the valve seats on the body.
2. Insert valve assembly in head and tighten. Close valve.

Reseating Cylinder Test Valve. A special tool is furnished for reseating the cylinder test valve.

1. Remove the valve.
2. Attach handle to reseating tool and place in valve hole in head.
3. Rotate tool in valve seat.

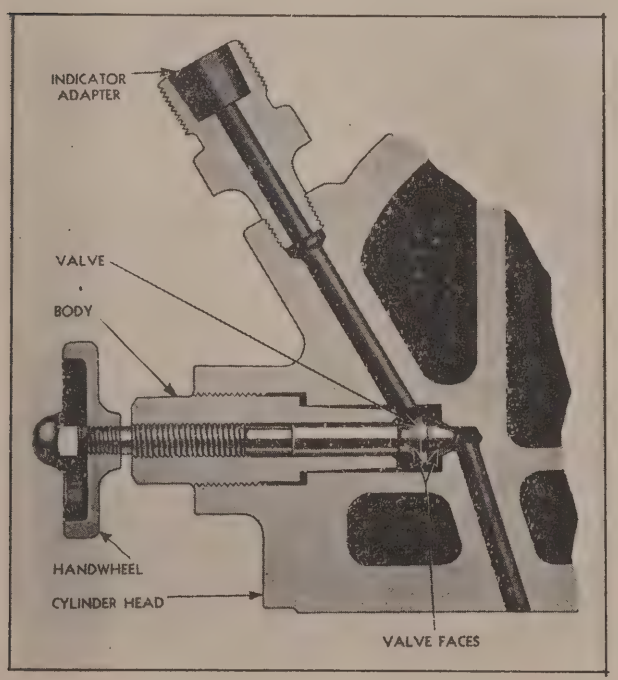


Fig. 16J
Cylinder Test Valve

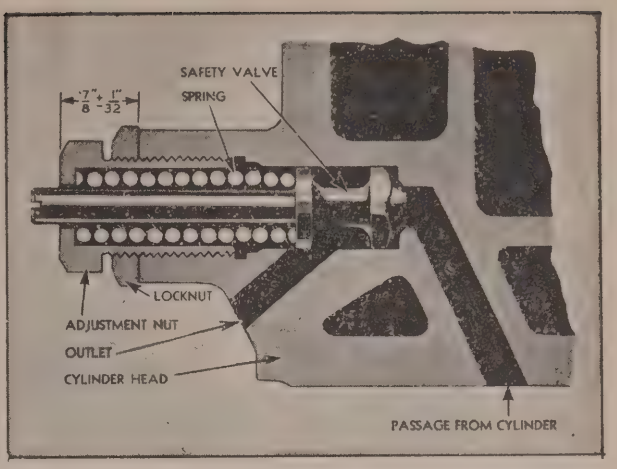


Fig. 17J
Cylinder Safety Valve

Cylinder Safety Valves

Description. Each cylinder head is equipped with a safety valve which opens if the cylinder pressures exceed a safe operating limit. The valve stem of the safety valve is held against its seat in the cylinder head by a spring, the compression of which is varied with the adjusting nut which also serves as the outer spring seat and valve guide.

Removing Cylinder Safety Valve.

1. Loosen locknut on valve body.
2. Unscrew adjustment nut to relieve spring tension and remove nut.
3. Pull valve stem and spring out of head.

Installing Cylinder Safety Valve.

1. The installation of the safety valve is the reverse of the removal procedure.
2. If the safety valve is removed for any reason, it must be reset so that the adjusting nut protrudes from the cylinder head about 7/8". (See Fig. 17J.)
3. After the valve is reinstalled and adjusted, the stem should be turned several times to insure that the valve is properly seated. This may be done by using a screw driver in the slotted end of the stem.

Air Starting Valves

The description and maintenance of the air distributor valve and the air starter check valve used in air started engines will be found in Section T.

CAMSHAFT DRIVE AND ACCESSORY DRIVE

Camshaft Drive

Description. The camshafts are driven from the power take off end of the crankshaft through a train of helical spur gears, with a crankshaft idler gear and a camshaft idler gear between the two camshaft gears and the crankshaft gear. The camshafts run at the same speed as the crankshaft but in the opposite direction of rotation. The drive gears for the lubricating oil pumps are driven from the camshaft drive gears. All gears are made of steel forgings.

All gears, except the lubricating oil pump drive gears in the camshaft drive are match marked at assembly so that if any gear is removed it can be reinstalled in its correct relationship with the other gears in the drive. The match-marks of the idler gears will line up at every revolution of the idler gears; however, all match-marks on all gears will line up only once in every 82 revolutions of the crankshaft when the piston in number one cylinder is at top dead center.

The split crankshaft gear is mounted loose on the crankshaft and held together with clamping bolts. The bore of the crankshaft gear is babbitted and a circumferential groove in the bearing forms the thrust surfaces which bear against a collar on the crankshaft. The crankshaft gear is driven through a spline ring on the elastic coupling.

Each of the two idler gears and lubricating oil pump drive gears are mounted on a heat treated steel shaft, which is pressed into the gear hub and is driven through a key. The two idler gear shafts are supported in inner and outer bearing supports fitted with single flanged steel bushings, which are lined with babbitt. The bearing supports are accurately aligned with dowel pins and fastened together with studs. The pump drive gears are supported in the bearing supports of their mating camshaft drive gears.

The camshaft drive gears are finished on the outside of the hub projections to form journals, and are supported in babbitt lined steel bushings which are pressed in the inner and outer bearing supports. The inner and outer bearing supports are accurately aligned with dowel pins and are fastened together with studs. The gear and bearing support assemblies are located accurately in the camshaft drive housing with dowels and fastened with studs.

The outer flange of each camshaft driving sleeve is fastened to the outer face of the camshaft gear hub by capscrews. The inner end of the driving sleeve is flanged and doweled to the flanged end of the camshaft. The camshaft is driven through the dowel pins in this connection, and a bolt, smaller than the dowel pins, prevents incorrect assembling of this drive connection. The holes in the outer flange of the driving sleeve are slotted, so that the camshaft may be accurately adjusted to the correct timing position. When this adjustment has been made, the timing position is permanently fixed by dowel pins, through which the driving sleeve and the camshaft are driven.

Oil for lubricating the gear teeth and the gear bearings is received from two oil distributing blocks

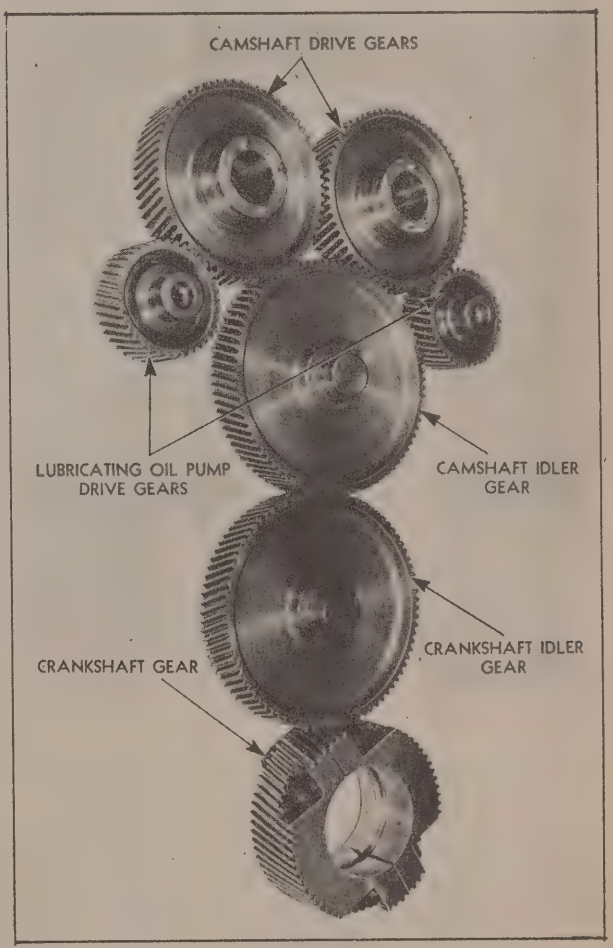


Fig. 1K
Relative Arrangement of Camshaft Drive Gears

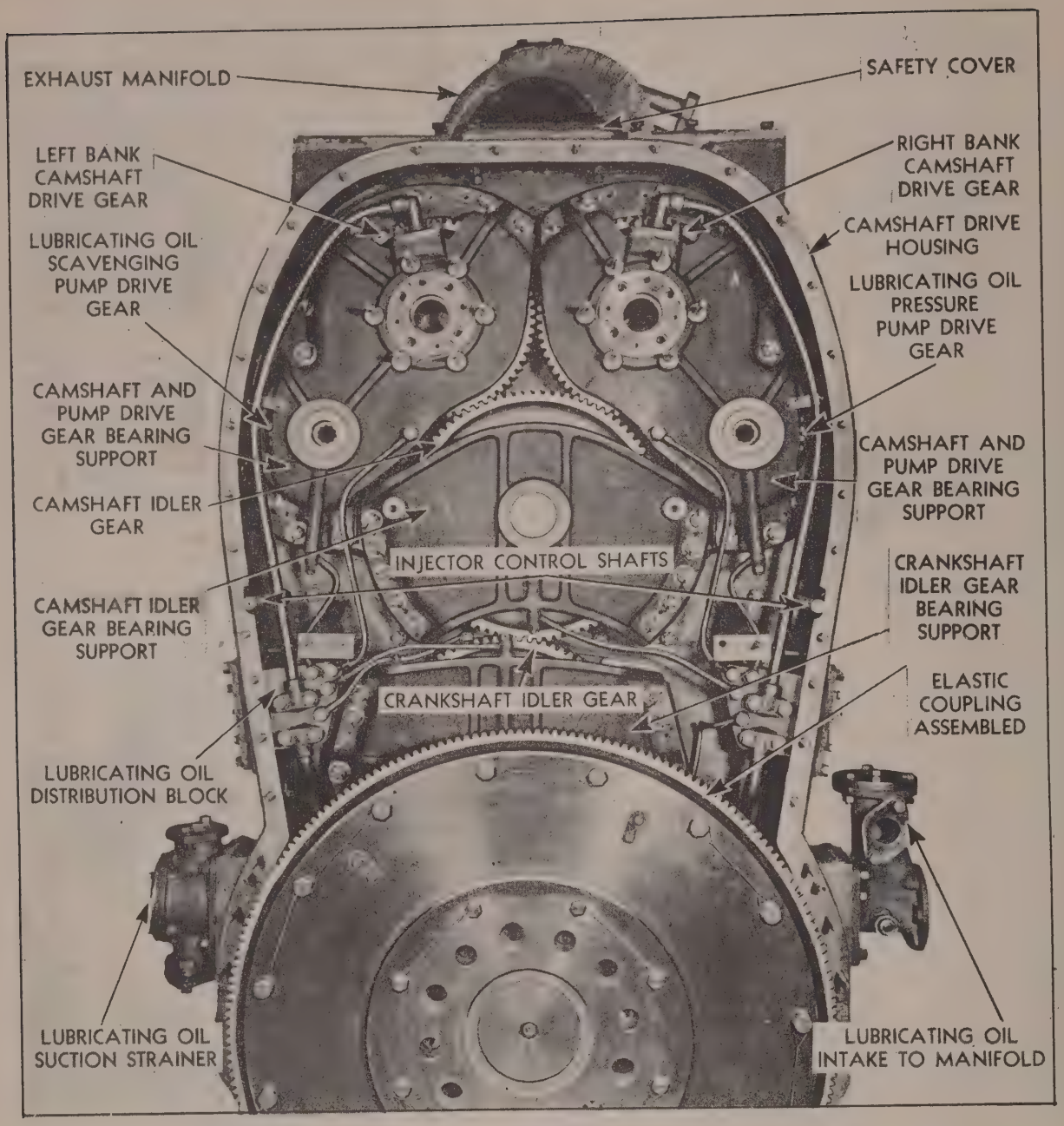

EXHAUST MANIFOLD
SAFETY COVER
LEFT BANK CAMSHAFT DRIVE GEAR
RIGHT BANK CAMSHAFT DRIVE GEAR
CAMSHAFT DRIVE HOUSING
LUBRICATING OIL SCAVENGING PUMP DRIVE GEAR
LUBRICATING OIL PRESSURE PUMP DRIVE GEAR
CAMSHAFT AND PUMP DRIVE GEAR BEARING SUPPORT
CAMSHAFT AND PUMP DRIVE GEAR BEARING SUPPORT
CAMSHAFT IDLER GEAR
INJECTOR CONTROL SHAFTS
CRANKSHAFT IDLER GEAR BEARING SUPPORT
CAMSHAFT IDLER GEAR BEARING SUPPORT
CRANKSHAFT IDLER GEAR
ELASTIC COUPLING ASSEMBLED
LUBRICATING OIL DISTRIBUTION BLOCK
LUBRICATING OIL SUCTION STRAINER
LUBRICATING OIL INTAKE TO MANIFOLD

Fig. 2K
Camshaft Drive Assembly

in the camshaft drive housing. The two distributing blocks are supplied with oil from the main manifold in the oil pan. The engaging gear teeth are lubricated with jets of oil delivered through tubes and nozzles. The outer bearings of all the gears, except the crankshaft gear, receive lubricating oil through tubes and drilled holes in the outer bearing supports. The inner bearings are lubricated with oil that is received from the outer bearings, through holes drilled in the gear hubs.

The gear train is enclosed in an oil-tight housing. The housing is accurately located on the end of the crankcase with dowel pins and is held in place with studs, some of which secure both the housing and the gear assemblies. A pressure relief opening in the top of the housing is fitted with a spring loaded plate.

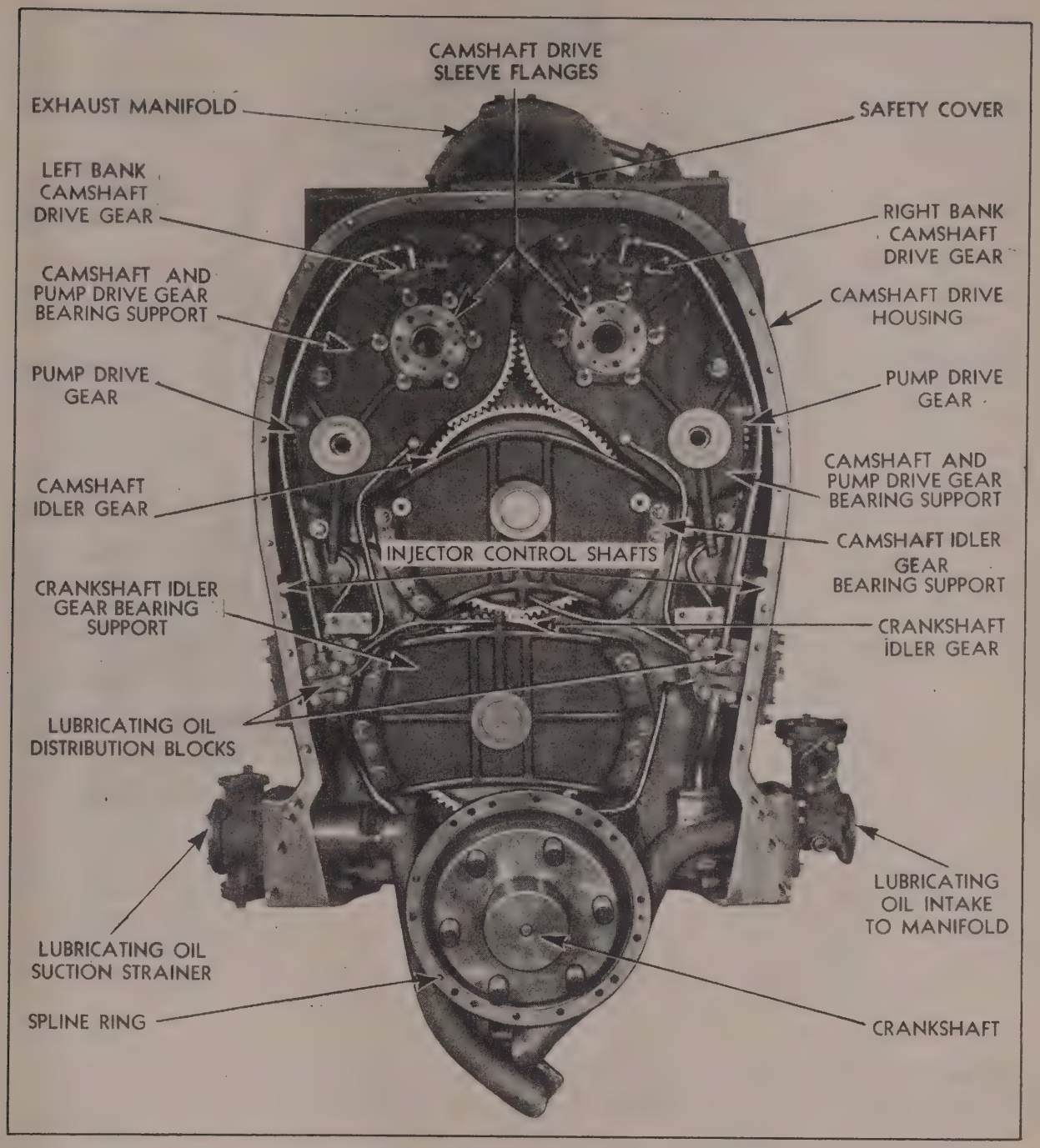


Fig. 3K
Camshaft Drive Elastic Coupling Removed

Maintenance. When one or more of the gears have been removed from the gear train, the crankshaft must not be rotated unless the rocker levers have been removed. If this is not done exhaust valves that are open will be damaged by the upward movement of the pistons. The camshaft drive cover should be removed periodically and the gear train inspected for excessive wear of any parts. Check all lubricating oil lines and passages to be sure they are not plugged.

Remove Camshaft Drive Cover.

1. Remove starting air valve and bracket if used. (See Section T.)
2. Remove governor and governor drive. (See Section M and page K-16.)

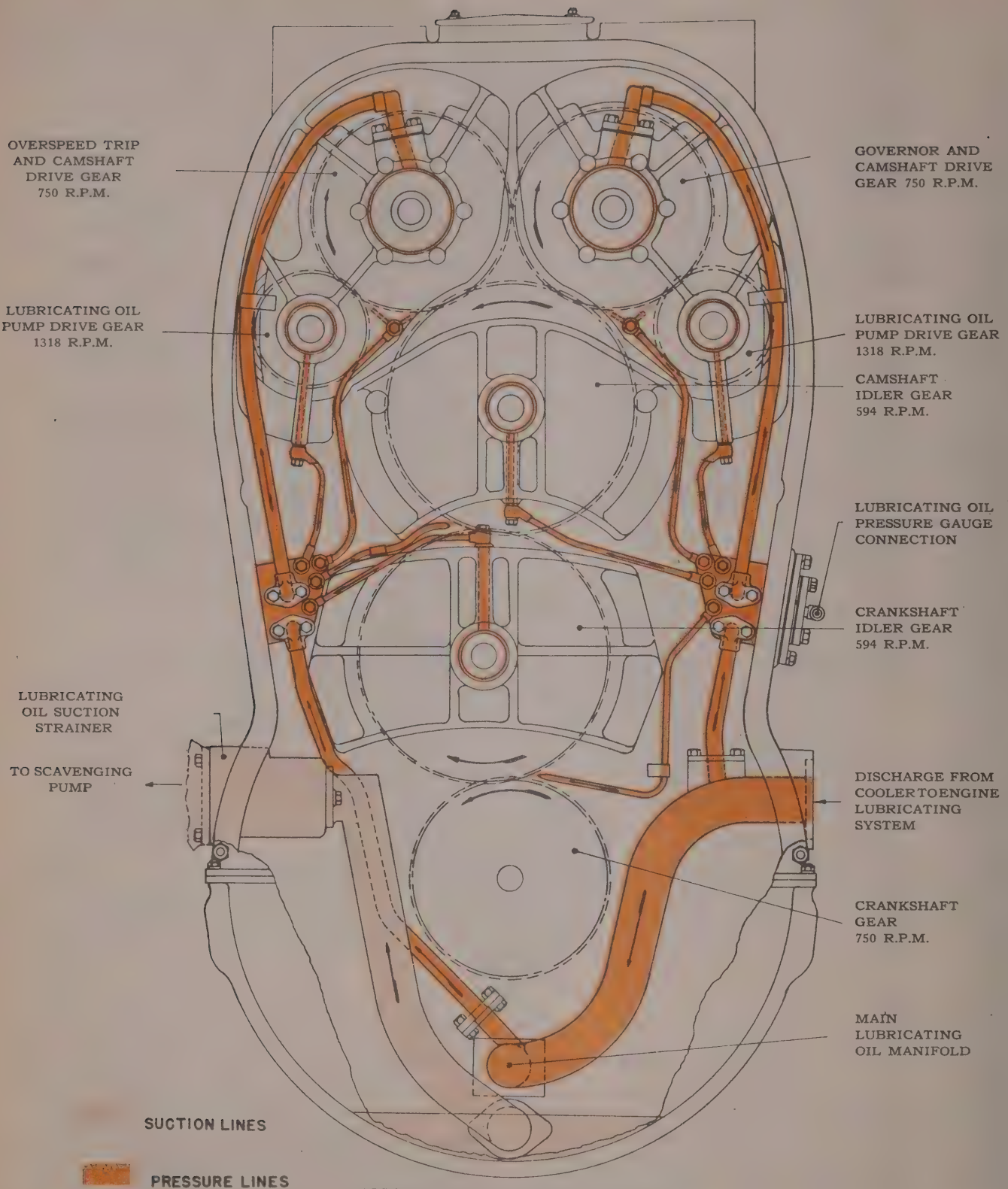

OVERSPEED TRIP AND CAMSHAFT DRIVE GEAR 750 R.P.M.
GOVERNOR AND CAMSHAFT DRIVE GEAR 750 R.P.M.
LUBRICATING OIL PUMP DRIVE GEAR 1318 R.P.M.
LUBRICATING OIL PUMP DRIVE GEAR 1318 R.P.M.
CAMSHAFT IDLER GEAR 594 R.P.M.
LUBRICATING OIL PRESSURE GAUGE CONNECTION
CRANKSHAFT IDLER GEAR 594 R.P.M.
LUBRICATING OIL SUCTION STRAINER
TO SCAVENGING PUMP
DISCHARGE FROM COOLER TO ENGINE LUBRICATING SYSTEM
CRANKSHAFT GEAR 750 R.P.M.
MAIN LUBRICATING OIL MANIFOLD
SUCTION LINES
PRESSURE LINES
ARROWS INDICATE DIRECTION OF ROTATION

Fig. 4K
Camshaft Drive Lubrication Diagram

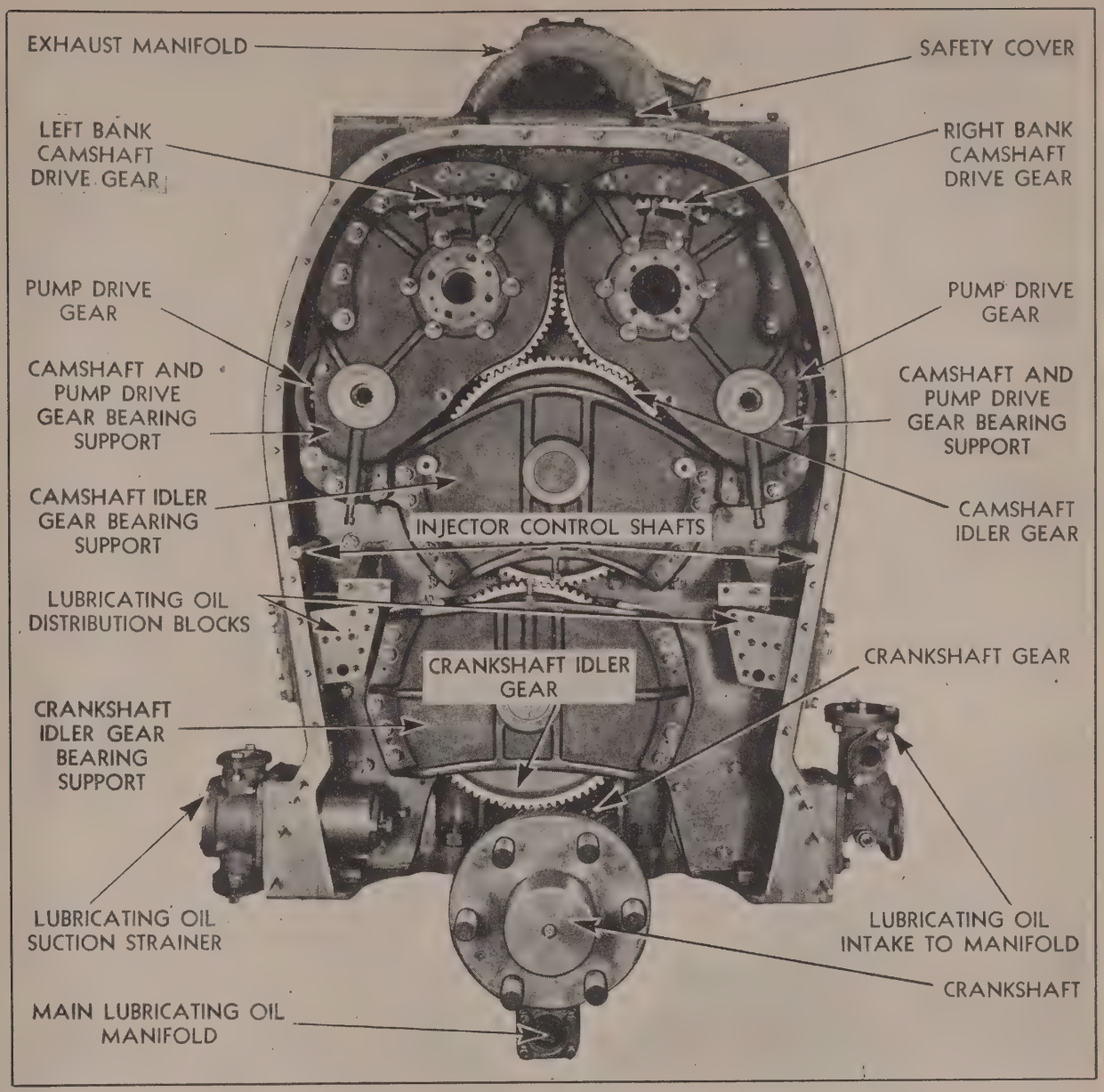


Fig. 5K
Camshaft Drive Oil Supply Lines Removed

3. Remove overspeed trip and overspeed trip drive. (See Section M and page K-17.)
4. Remove lubricating oil regulating and relief valve. (See Section P.)
5. Remove lubricating oil pressure pump. (See Section P.)
6. Remove lubricating oil scavenging pump. (See Section P.)
7. Remove injector control linkage and levers. (See Section N.)
8. Remove upper flywheel housing (See Section F.)
9. Remove capscrews and lockwashers holding cover to housing.
10. Attach hoist and remove cover.

Install Camshaft Drive Cover.

1. Inspect cover gasket for damage. Shellac new gasket to cover if damaged.
2. Balance of installation is the reverse of removal.

Remove Crankshaft Gear.

1. Remove elastic coupling. (See Section F.)
2. Remove camshaft drive housing cover. (See page K-3.)
3. Remove lubricating oil line from engine inlet to main manifold.
4. Remove lubricating oil line from main manifold to left bank distribution block.
5. Match-mark, with crayon or chalk, the mating teeth of the crankshaft gear and the crankshaft idler gear, the crankshaft idler gear and the camshaft idler gear.
6. Remove crankshaft idler gear. (See below.)
7. Block under crankshaft gear to prevent turning or dropping.
8. Remove crankshaft gear clamp bolts.
9. Remove lower half of crankshaft gear.
10. Remove upper half of crankshaft gear.

Note: When a new crankshaft gear is to be installed, it is necessary to match-mark the gear as follows:

1. Match-mark, with the figure "1," one of the teeth on the new gear.
2. Count the number of teeth on the worn gear between the permanent match-mark and the temporary chalk mark, and mark, with chalk, the corresponding tooth of the new gear.

Install Crankshaft Gear.

1. Be sure elastic coupling inner spring holder bolts are in the crankshaft flange.
2. Place lower half of crankshaft gear on underside of crankshaft with the shoulder toward the cylinder block. Block gear to hold in place.

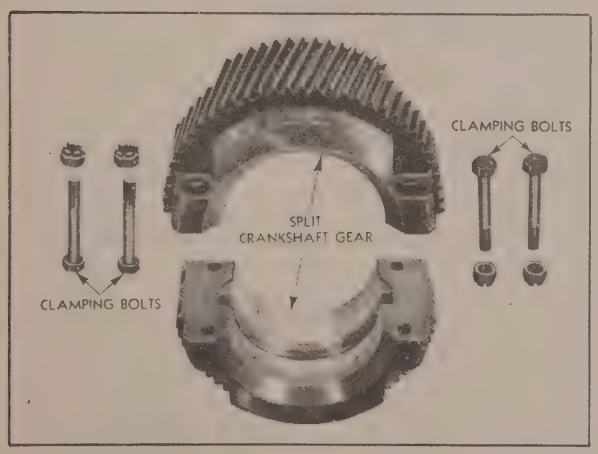


Fig. 6K
Crankshaft Gear

3. Place upper half crankshaft gear over crankshaft with shoulder toward cylinder block.
4. Install clamping bolts and nuts, tighten. Install cotter pins.
5. Line up temporary match-marks, on crankshaft gear, and crankshaft idler gear, and on crankshaft idler gear and camshaft idler gear, and install crankshaft idler gear.
6. Install lubricating oil lines.
7. Install camshaft drive housing cover.
8. Install elastic coupling. (See Section F.)

Remove Crankshaft Idler Gear and Bearing Support.

1. Remove elastic coupling. (See Section F.)
2. Remove camshaft drive housing cover. (See page K-3.)
3. Remove lubricating oil line from distributing block to crankshaft idler gear outer bearing support.
4. Remove upper and lower spray tubes.
5. Match-mark, with crayon or chalk, the mating teeth of the camshaft idler gear and the crankshaft idler gear, and the mating teeth of the crankshaft idler gear and the crankshaft gear.
6. Pull the upper left and lower right bearing support dowels out about ½" by the washer stack method.
7. Remove only the castellated nuts from the bearing support studs marked "Remove Nuts" on Fig. 7K and remove gear and support assembly.

Note: When a new crankshaft idler gear is to be installed, proceed as follows:

1. Remove idler gear from bearing support. (See page K-10.)
2. Place new gear and worn gear side by side on bench and note position of match mark "1" on worn gear. Stamp figure "1" at a corresponding position on new gear.
3. Count the teeth between the match mark "1" and the match mark "2" on the worn gear. Stamp figure "2" at corresponding position on new gear.
4. Count the teeth between stamped match marks and temporary chalk mark on the worn gear and mark corresponding position on new gear with chalk.
5. Install new idler gear in bearing supports. (See page K-10.)

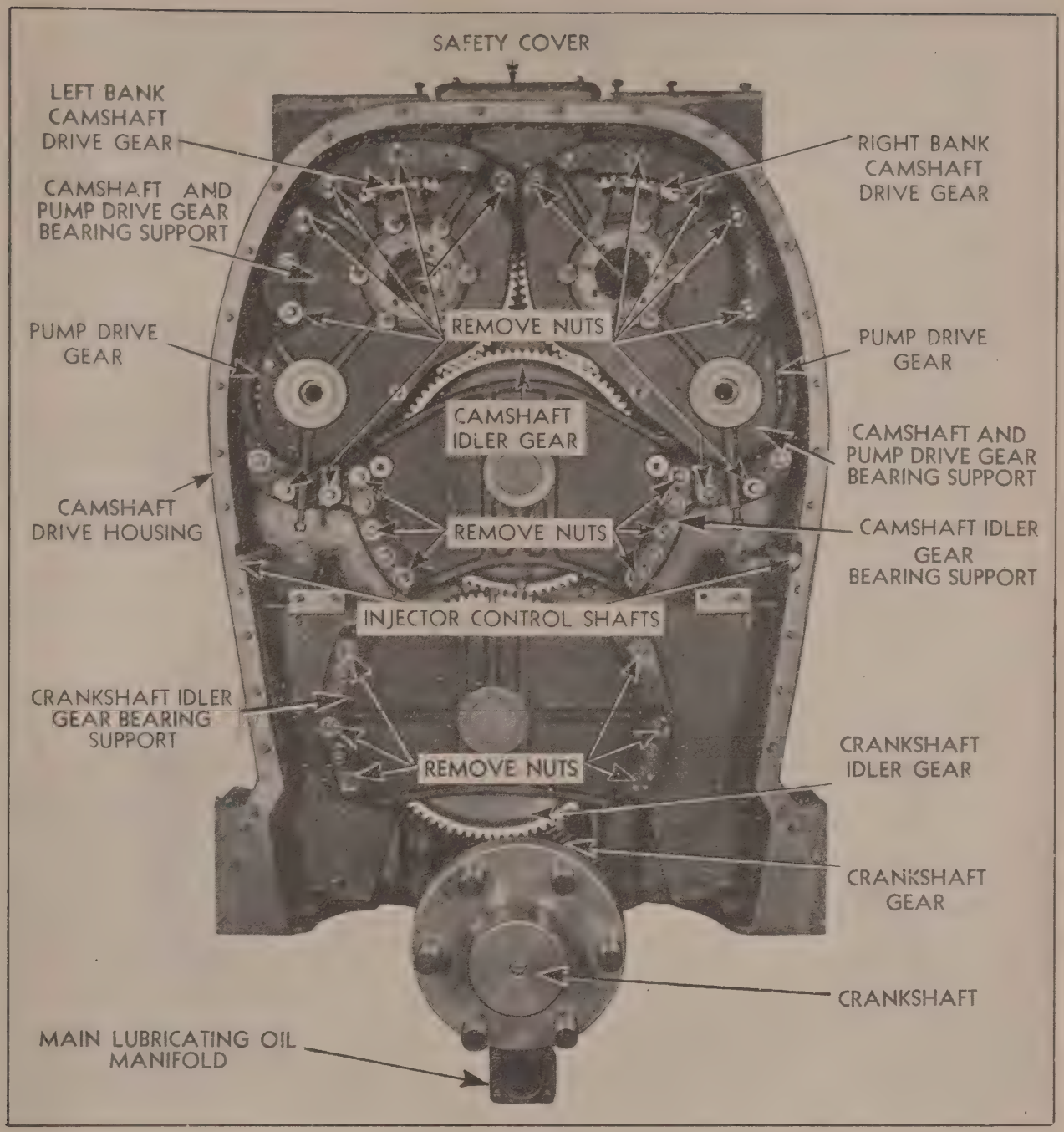


Fig. 7K
Camshaft Drive Bearing Support Nuts Removed

Install Crankshaft Idler Gear and Bearing Support.

1. Drive upper left and lower right locating dowels through bearing support assembly until they project about 1/8" from face of inner bearing support.
2. Line up temporary match marks on gears and slide assembly into place over studs.
3. Locate assembly in housing with locating dowels and start dowels by tapping assembly lightly with lead hammer until inner bearing support is tight against housing bosses.

4. Drive the locating dowels into the housing until they are flush with the outer bearing support flange.
5. Install castellated nuts and tighten. Install cotter pins.

Remove Camshaft Idler Gear and Bearing Support.

1. Remove camshaft drive cover. (See page K-3.)
2. Remove lubricating oil line from distribution block to camshaft idler gear outer bearing support.
3. Match-mark, with crayon or chalk, the mating teeth of the camshaft idler gear and both camshaft gears, and the mating teeth of the camshaft idler gear and the crankshaft idler gear.
4. Pull the upper left and lower right bearing support dowels out about ½" by the washer stack method.
5. Remove only the castellated nuts from the bearing support studs marked "Remove Nuts" on Fig. 7K and remove gear and support assembly.

Note: When a new camshaft idler gear is to be installed, proceed as follows:

1. Remove idler gear from bearing supports. (See page K-10.)
2. Place new idler gear and worn idler gear side by side on bench and note position of match-mark "2" on worn gear. Stamp figure "2" at a corresponding position on the new gear.
3. Count the teeth between the match-mark "2" and the match-marks "3" and "4" on the worn gear. Stamp figures "3" and "4" at corresponding positions on new gear.
4. Count the teeth between the stamped match-marks and the temporary chalk marks on the worn gear and mark the new gear at corresponding positions with chalk or crayon.
5. Install new camshaft idler gear in bearing supports. (See page K-10.)

Install Camshaft Idler Gear and Bearing Support.

1. Drive upper left and lower right locating dowels through bearing support assembly until they project about ⅛" from face of inner bearing support.
2. Line up temporary match-marks on gears and slide assembly into place over studs.
3. Locate assembly in housing with locating dowels and start dowels by tapping assembly lightly with lead hammer until inner bearing support is tight against housing bosses.
4. Drive the locating dowels into the housing until they are flush with the outer bearing support flange.
5. Install castellated nuts and tighten. Install cotter pins.

Remove Camshaft Drive Gear Assembly. (Including or not including pump drive gear.)

1. Remove camshaft drive cover. (See page K-3.)
2. Remove lubricating oil lines from distribution block to camshaft drive gear outer bearing support.
3. Remove castellated nuts from camshaft and drive sleeve connection. (See Section L.)
4. Match-mark, with chalk or crayon, the mating teeth of the camshaft gear and the camshaft idler gear.
5. Remove camshaft drive sleeves. (See Section L.)
6. Remove the outer of the two upper dowels and the inner of the two lower dowels.
7. Remove the castellated nuts from the bearing support studs marked "Remove Nuts" on Fig. 7K and remove gear and support assembly.

Install New Camshaft Drive Gear.

1. Place camshaft gear and bearing support assembly on convenient bench and remove dowels.
2. Remove castellated nuts from studs.
3. Lift off outer bearing support and remove camshaft gear and pump drive gear, if used.
4. Place a straight edge across the center of the capscrew hole in the gear hub, nearest the lubricating oil hole, and across the center of the diametrically opposite capscrew hole. Count the teeth between the straight edge and the match-mark stamped in the worn camshaft gear.
5. Temporarily mark the corresponding tooth on new camshaft gear with a prick punch.
6. Count the teeth between the stamped match-mark and the chalk mark on the worn gear and mark the corresponding tooth on the new gear with chalk.
7. Oil the gear bearings and place new gear or gears in inner bearing support.

8. Place outer bearing support over gear or gears and install dowel pins.
9. Install castellated nuts, tighten and install cotter pins.
10. Line up the chalk marks on the camshaft and camshaft idler gears and install camshaft gear and bearing support assembly.
11. Line up the oil hole in the drive sleeve with the oil hole in the camshaft gear hub and install drive sleeve on dowels in camshaft. Do not install nuts on dowels until drive sleeve has been bolted to camshaft gear. Use short temporary capscrews to fasten the drive sleeve to the camshaft gear.
12. Turn the engine over so that the cam roller of the valve rocker lever of the cylinder being used for timing the camshaft is riding on the lowest point of its operating cam. Remove all slack but do not tighten enough to open the valves.
    a. When the right bank camshaft gear is renewed use cylinder No. 1 for checking the timing.
    b. When the left bank camshaft gear, on a left hand rotation engine is renewed, use cylinder No. 7.
    c. When the left bank camshaft gear, on a right hand rotation engine is renewed use cylinder No. 11.
13. Clamp a dial indicator to a convenient solid point so that the indicator contact point rests on the upper end of the rocker lever adjusting screw from which the slack was removed. Set the dial indicator at zero.
14. Turn the crankshaft over to the timing position of the camshaft to be timed. (See Fig. 8K.)
    a. *The right bank camshaft on either right or left hand rotation engines.* The joint between the cylinder block and the oil pan at the control side of the engine is even with the 121° mark on the elastic coupling.
    b. *The left bank camshaft on a left hand rotation engine.* The joint between the cylinder block and the oil pan at the control side of the engine even with the 161° mark on the elastic coupling.
    c. *The left bank camshaft on a right hand rotation engine.* The joint between the cylinder block and the oil pan at the control side of the engine even with the 141° mark on the elastic coupling.
15. Loosen the capscrews in the slots in the camshaft drive sleeve flange and turn the camshaft until the dial indicator shows that the exhaust valves are open 0.015″. Tighten the capscrews.

    Note: If the capscrews stop against the ends of the slots in the drive sleeve flange before the valves are open 0.015″ the camshaft idler gear must be removed (See page K-8) and remeshed with another tooth on the camshaft gear. Do not change the mesh between the camshaft idler gear and the crankshaft idler gear.
16. When the correctly meshed position of the camshaft gear is found, the capscrews in the driving sleeve are tightened.
17. Turn the crankshaft in a counter-rotational direction 10° or 15° and return to the timing position. If the dial indicator shows that the exhaust valves are open 0.015″ the camshaft is correctly timed.
18. Drill, ream, and dowel the camshaft drive sleeve to the camshaft gear. Remove the temporary capscrews.
19. Turn the crankshaft in the direction of rotation until piston in cylinder No. 1 is at top dead center (the joint between the cylinder block and oil pan, at the control side of the engine is even with the 20° mark on the elastic coupling).
20. Match-mark the mating tooth of the camshaft gear only with the Number 3 when a right bank camshaft gear is renewed. Match-mark mating tooth of the camshaft gear only with the Number 4 if the left bank camshaft gear is renewed. These marks may not line up with the match-marks of the mating camshaft idler gear, but should coincide with the prick punch marks on the camshaft drive gear, unless it was necessary to remesh the camshaft drive gear (Step 15).

Install Same Camshaft Drive Gear.

1. Drive the outer of the two upper dowels, and the inner of the two lower dowels through bearing support assembly until they project about ⅛″ from face of inner bearing support.
2. Line up temporary match-marks on mating gears and slide assembly into place over studs.
3. Locate assembly in housing with locating dowels and start dowels by tapping assembly lightly with lead hammer until inner bearing support is tight against housing bosses.

4. Drive the locating dowels into housing until they are flush with the outer bearing support flange.
5. Install castellated nuts, tighten and cotter key.
6. Install camshaft drive sleeve. Be sure the lubricating oil hole in the drive sleeve lines up with the oil hole in the gear hub.

Remove Gear from Bearing Supports. To further disassemble any of the gear and bearing support assemblies proceed as follows:

1. Remove dowels.
2. Remove castellated nuts from studs.
3. Lift off outer bearing support and remove gear.

Install Gear in Bearing Supports.

1. Oil bearings and gears. Place gear in inner bearing support.
2. Place outer bearing support over gear and studs, line up dowel holes and drive in dowels.
3. Install castellated nuts and tighten. Install cotter pins.

Remove Lubricating Oil Distribution Manifold

1. Remove camshaft drive cover. (See page K-3.)
2. Disconnect all lubricating oil lines at distribution manifold.
3. Remove nuts and lockwashers holding distribution manifold to camshaft drive housing and pull out manifold.

Install Lubricating Oil Distribution Manifold.

1. Reverse the removal procedure.

Remove Camshaft Drive Housing.

1. Remove elastic coupling. (See Section F.)
2. Remove camshaft drive cover. (See page K-3.)
3. Remove crankshaft idler gear. (See page K-6.)
4. Remove camshaft idler gear. (See page K-8.)
5. Remove camshaft gears. (See page K-8.)
6. Remove lubricating oil distribution manifolds. (See above.)
7. Remove lubricating oil main bearing manifold connection.
8. Remove engine inlet lubricating oil connection.
9. Remove lubricating oil suction strainer. (See Section P.)
10. Remove castellated nuts holding housing to cylinder block.
11. Attach hoist and remove housing.

Install Camshaft Drive Housing.

1. Inspect gasket on housing. Shellac new gasket to housing if damaged.
2. Balance of installation is reverse of removal.

Assembling Camshaft Drive Gear Train.

When the entire camshaft drive gear train is renewed with new gears the camshafts must be timed in order to determine the proper relationship between the camshafts and the crankshaft. After the crankshaft gear, crankshaft idler gear, and the elastic coupling have been match-marked and installed, the camshafts are properly timed as follows:

Timing Right Bank Camshaft—Left and Right Hand Rotation Engines.

1. Remove all rocker lever assemblies with the exception of cylinder No. 1 in the right bank. (See Section J.)
2. Open all cylinder test valves.
3. Turn the camshaft so that cam roller is riding on lowest point of cam and remove all slack from one pair of valves with the rocker lever adjusting screw. Do not tighten enough to open valves.

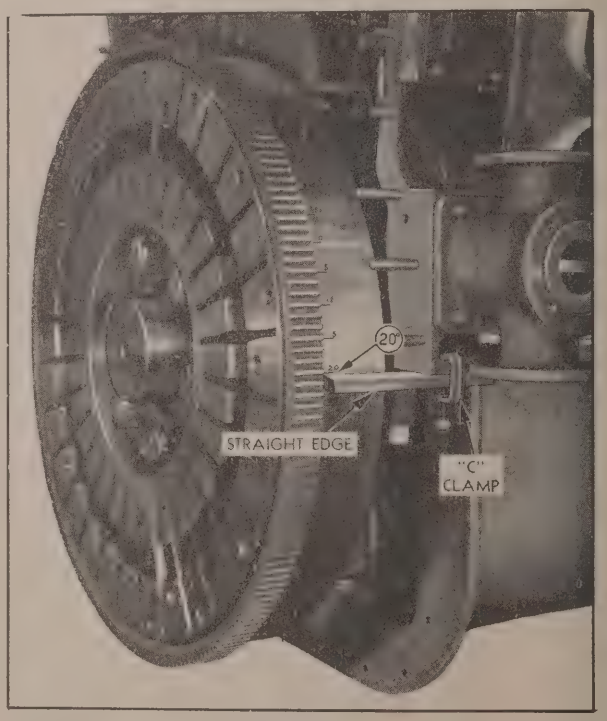


Fig. 8K
Piston No. 1 in Top Dead Center Position

4. Install camshaft idler gear inner bearing support in the camshaft drive housing.
5. Turn the crankshaft in the direction of rotation until the piston in cylinder No. 1 is at top dead center and all match-marks are lined up properly. When the joint between the cylinder block and the oil pan on the control side of the engine is even with the 20° mark on the elastic coupling, the piston in cylinder No. 1 is at the top dead center position. (See Fig. 8K.)
6. Place the camshaft idler gear in the inner bearing support so that the match-mark (Number 2) lines up with the crankshaft idler gear. Install outer bearing support and hold with a nut on each side.
7. Turn the crankshaft in the direction of rotation until the joint between the cylinder block and the oil pan of the control side of the engine is even with the 121° mark on the elastic coupling.
8. Mark the mating teeth of the crankshaft and camshaft idler gears in this position with chalk and remove the camshaft idler gear outer bearing support and idler gear.
9. Install the right bank camshaft gear and bearing support assembly.
10. Line up oil hole in camshaft gear with camshaft driving sleeve and bolt driving sleeve to camshaft gear. The full length capscrews that are used for fastening the driving sleeve to the camshaft gear in the final assembly are too long to use in the timing operation and shorter temporary capscrews must be used. These capscrews should be tightened at the middle of the slotted holes in the driving sleeve flange. Holes for the dowels should not be drilled until after the final adjustment
11. Fasten the camshaft driving sleeve to the camshaft. Install lockwire. The small nut and bolt locates the camshaft driving sleeve with respect to the camshaft. Replace camshaft intermediate cover.
12. Clamp a dial indicator to a convenient solid point so that the indicator contact point rests on the upper end of the rocker lever adjusting screw for the pair of valves from which the slack was removed in step 3. Set the indicator at zero.
13. With the crankshaft set at 101° after top dead center of cylinder No. 1 (joint between cylinder block and oil pan at the control side of the engine even with 121° mark on the elastic coupling) turn the camshaft until the dial indicator shows that the exhaust valves are open 0.015″.
14. Mesh the teeth of the camshaft idler gear with the camshaft gear and the crankshaft idler gear so that the chalk marks on the camshaft and crankshaft idler gears line up. Turn the camshaft gear, if necessary, to place the camshaft idler gear hub in the inner bearing support. Install camshaft gear outer bearing support and hold with a nut on each side.
15. Loosen the capscrews in the slots in the camshaft driving sleeve flange and turn the camshaft until the dial indicator shows that the exhaust valves are again open 0.015″. Tighten the capscrews.

    Note: If the capscrews stop against the ends of the slots in the driving sleeve flange before the valves are open 0.015″ the camshaft idler gear must be remeshed with another tooth on the camshaft gear. Do not change the mesh between the camshaft and crankshaft idler gears.
16. When the correctly meshed position of the camshaft gear is found the capscrews in the driving sleeve flange are tightened.
17. Turn the crankshaft in a counter rotational direction 10° or 15° and return to the timing position. If the dial indicator shows that the exhaust valves are open 0.015″ the camshaft is correctly timed.
18. Drill, ream, and dowel the camshaft driving sleeve to the camshaft gear.
19. Turn crankshaft in a counter rotational direction to 10° or 15° before top dead center of cylinder No. 1 and then turn crankshaft in direction of rotation until piston in cylinder No. 1 is at top dead center (joint between cylinder block and oil pan at the control side of the engine is even with 20° mark on the elastic coupling). Match-marks on all gears should line up. (See paragraph 2 on page K-1.) Match-mark camshaft gear and camshaft idler gear with Number 3.

Timing Left Bank Camshaft—Left Hand Rotation Engine.

1. Turn crankshaft in the direction of rotation so that the piston in cylinder No. 7 is 101° after top dead center (joint between cylinder block

and oil pan at the control side of the engine even with the 161° mark on the elastic coupling).

2. Temporarily match-mark with chalk the meshing teeth on the camshaft idler gear, crankshaft idler gear, and right bank camshaft gear. Remove camshaft idler gear outer bearing support and idler gear.
3. Replace rocker levers on cylinder No. 9.
4. Install the left bank camshaft gear and bearing support assembly.
5. Line up oil hole in camshaft gear with camshaft driving sleeve and bolt driving sleeve to camshaft gear. The full length capscrews that are used for fastening the driving sleeve to the camshaft gear in the final assembly are too long to use in the timing operation and shorter temporary capscrews must be used. These capscrews should be tightened at the middle of the slotted holes in the driving sleeve flange. Holes for the dowels should not be drilled until after the final adjustment.
6. Fasten the camshaft driving sleeve to the camshaft. Install lockwire. The small nut and bolt locates the camshaft driving sleeve with respect to the camshaft. Replace camshaft intermediate cover.
7. Turn the left bank camshaft so that cam roller is riding on lowest point of cam and remove all slack from one pair of valves with the rocker lever adjusting screw. Do not tighten enough to open valves.
8. Clamp a dial indicator to a convenient solid point so that the indicator contact point rests on the upper end of the rocker lever adjusting screw for the pair of valves from which all slack was removed in step 7. Set the indicator at zero.
9. With the crankshaft set at 101° after top dead

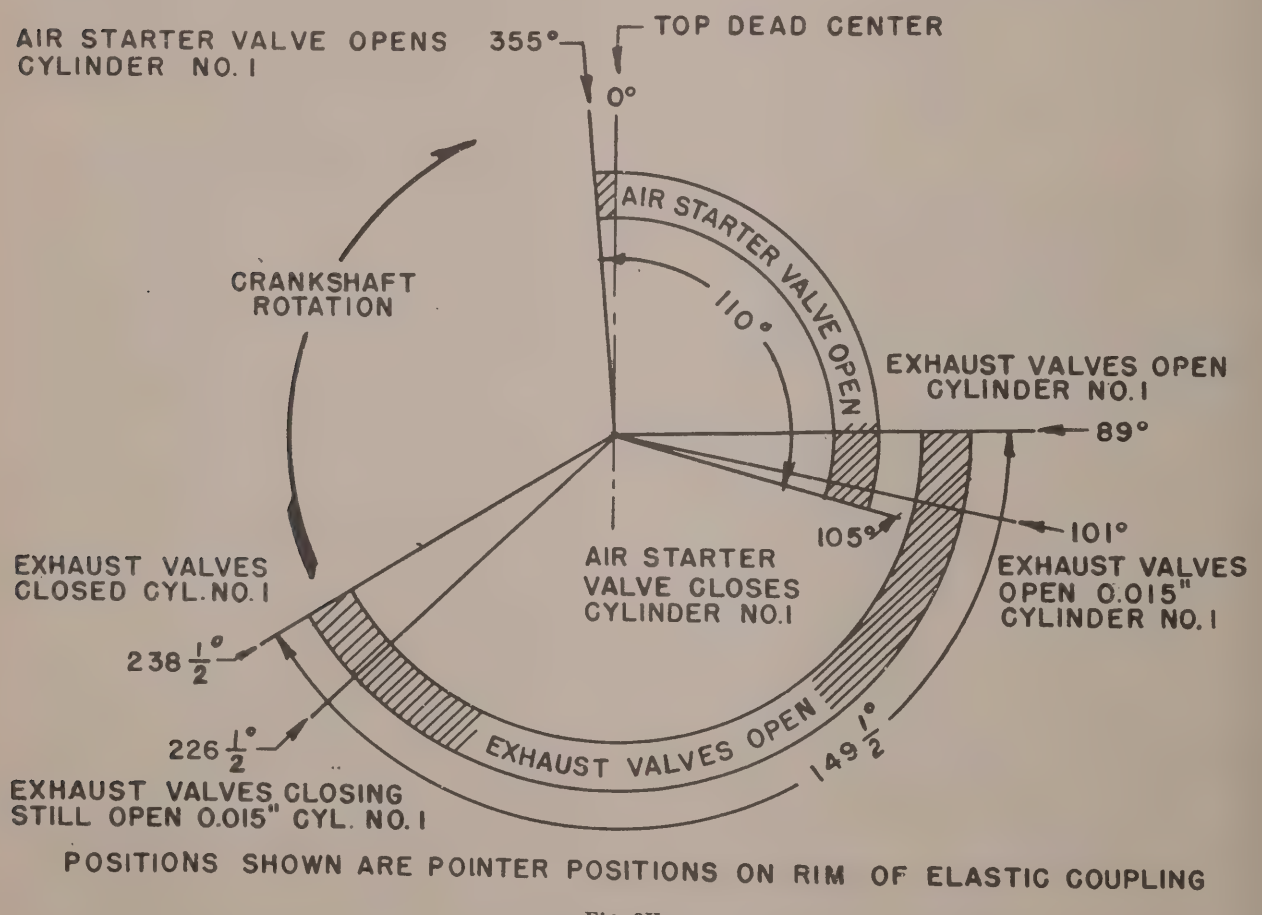


Fig. 9K
Valve Timing Diagram

center of cylinder No. 9 (joint between cylinder block and oil pan on the control side of the engine even with 161° mark on the elastic coupling) turn the left bank camshaft until the dial indicator shows that the exhaust valves are open 0.015".

10. Install camshaft idler gear so that chalk marks line up with those on crankshaft idler gear and right bank camshaft gear. Install camshaft idler gear outer bearing support and hold with a nut on each side.
11. Turn left bank camshaft gear, if necessary, to mesh teeth of camshaft gear and camshaft idler gear.
12. Loosen the capscrews in the slots in the camshaft driving sleeve flange and turn the camshaft until the dial indicator shows that the exhaust valves are again open 0.015". Tighten the capscrews.

    Note: If the capscrews stop against the ends of the slots in the driving sleeve flange before the valves are open 0.015", the camshaft idler gear must be remeshed with another tooth on the camshaft gear. Do not change the mesh between the camshaft and crankshaft idler gears, or between the camshaft idler gear and the right bank camshaft gear.
13. When the correctly meshed position of the camshaft gear is found the capscrews in the driving sleeve flange are tightened.
14. Turn the crankshaft in a counter rotational direction 10° or 15° and return to the timing position. If the dial indicator shows that the exhaust valves are open 0.015" the camshaft is correctly timed.
15. Drill, ream, and dowel the camshaft driving sleeve to the camshaft gear.
16. Turn crankshaft in a counter rotational direction to 10° or 15° before top dead center of cylinder No. 1 and then turn crankshaft in direction of rotation until piston in cylinder No. 1 is at top dead center (joint between cylinder block and oil pan on the control side of the engine even with 20° mark on the elastic coupling). Match-marks on all gears should line up. (See paragraph 2 on page K-1.) Match-mark left bank camshaft gear and camshaft idler gear with Number 4. Remove temporary capscrews from both camshaft gears and driving sleeves.
17. Install remaining castellated nuts on camshaft idler gear bearing support studs, tighten and cotter key.
18. Install remaining rocker lever assemblies.

Timing Left Bank Camshaft—Right Hand Rotation Engine.

1. Turn crankshaft in the direction of rotation so that the piston in cylinder No. 15 is 101° after top dead center (joint between cylinder block and oil pan on the control side of the engine even with the 126° mark on the elastic coupling).
2. Temporarily match-mark with chalk the meshing teeth on the camshaft idler gear, crankshaft idler gear, and right bank camshaft gear. Remove camshaft idler gear.
3. Replace rocker levers on cylinder No. 15.
4. Install the left bank camshaft gear and bearing support assembly.
5. Line up oil hole in camshaft gear with camshaft driving sleeve to camshaft gear. The full length capscrews that are used for fastening the driving sleeve to the camshaft gear in the final assembly are too long to use in the timing operation and shorter temporary screws must be used. These capscrews should be tightened at the middle of the slotted holes in the driving sleeve flange. Holes for the dowels should not be drilled until after the final adjustment.
6. Fasten the camshaft driving sleeve to the camshaft. Install lockwire. The small nut and bolt locates the camshaft driving sleeve with respect to the camshaft. Replace camshaft intermediate cover.
7. Turn the left bank camshaft so that cam roller is riding on lowest point of cam and remove all slack from one pair of valves with the rocker lever adjusting screw. Do not tighten enough to open valves.
8. Clamp a dial indicator to a convenient solid point so that the indicator contact point rests on the upper end of the rocker lever adjusting screw for the pair of valves from which all slack was removed in step 7. Set the indicator at zero.
9. With the crankshaft set at 101° after top dead center of cylinder No. 15 (joint between cylinder block and oil pan on the control side of the engine at 126° mark on the elastic

coupling) turn the left bank camshaft until the dial indicator shows that the exhaust valves are open 0.015".

10. Install camshaft idler gear so that chalk marks line up with those on crankshaft idler gear and right bank camshaft gear. Install camshaft idler gear outer bearing support and hold with a nut on each side.

11. Turn left bank camshaft gear, if necessary, to mesh teeth of camshaft gear and camshaft idler gear.

12. Loosen the capscrews in the slots in the camshaft driving sleeve flange and turn the camshaft until the dial indicator shows that the exhaust valves are again open 0.015". Tighten the capscrews.

Note: If the capscrews stop against the ends of the slots in the driving sleeve flange before the valves are open 0.015", the camshaft idler gear must be remeshed with another tooth on the camshaft gear. Do not change the mesh between the camshaft and crankshaft idler gears, or between the camshaft idler gear and the right bank camshaft gear.

13. When the correctly meshed position of the camshaft gear is found the capscrews in the driving sleeve flange are tightened.

14. Turn the crankshaft in a counter rotation direction 10° or 15° and return to the timing position. If the dial indicator shows that the exhaust valves are open 0.015" the camshaft is correctly timed.

15. Drill, ream, and dowel the camshaft driving sleeve to the camshaft gear.

16. Turn crankshaft in a counter rotational direction to 10° or 15° before top dead center of cylinder No. 1 and then turn crankshaft in direction of rotation until piston in cylinder No. 1 is at top dead center (joint between cylinder block and oil pan at control side of engine even with 20° mark on the elastic coupling). Match-marks on all gears should line up. (See paragraph 2 on page K-1.) Match-mark left bank camshaft gear and camshaft idler gear with Number 4. Remove temporary capscrews from both camshaft gears and driving sleeves.

17. Install castellated nuts on camshaft idler bearing support studs, tighten and cotter key.

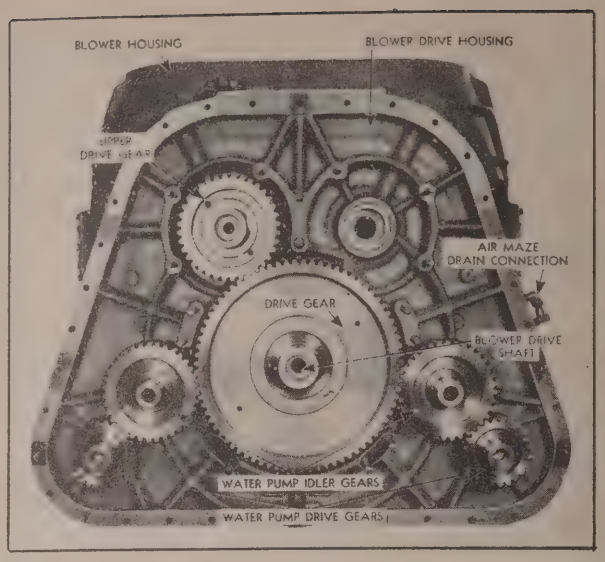


Fig. 10K
Accessory Drive Assembly

18. Install remaining rocker lever assemblies.

Accessory Drive

Description. The accessory drive is located on the blower end of the engine and consists of a train of helical gears transmitting the rotation of the crankshaft to the blower and water pumps. The gears are enclosed in a case bolted to the blower housing.

The blower and accessory drive gear, which drives the water pump idler gears and the blower drive gear, is driven from the crankshaft through a splined shaft, one end of which fits into a hub that is bolted

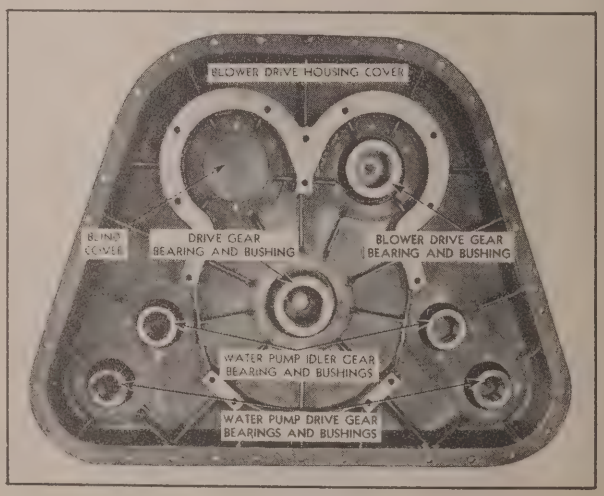

BLOWER DRIVE HOUSING COVER
BLIND COVER
DRIVE GEAR BEARING AND BUSHING
BLOWER DRIVE GEAR BEARING AND BUSHING
WATER PUMP IDLER GEAR BEARING AND BUSHINGS
WATER PUMP DRIVE GEAR BEARINGS AND BUSHINGS

Fig. 11K
Accessory Drive Cover

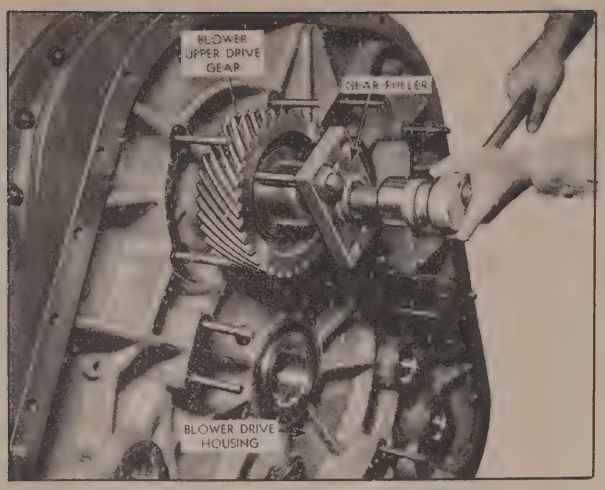


Fig. 12K
Removing Blower Upper Drive Gear

to the crankshaft while the other end fits into the blower drive gear hub. The water pump drive gears are driven by the idler gears. All gears are steel forgings and have integral shafts. The inner gear bearings are babbitt lined with integral thrust faces and are pressed into the housing. The outer bearings are pressed into the housing cover plates, which are bolted to the accessory drive cover.

Oil for lubricating the gear bearings is received from a manifold bolted to the main lubricating oil manifold, which carries oil to passages formed by steel tubing cast into the ribs of the drive housing. The outer bearings are lubricated by oil flowing through passages in the gear hubs.

Maintenance. The accessory drive cover should be removed periodically and the gear train inspected for excessive wear of any parts. Check the lubricating oil passages to be sure they are not plugged.

Remove Accessory Drive.

1. Remove Air Maze and drain line. (See Section S.)
2. Remove sea and fresh water pumps. (See Section R.)
3. Remove accessory drive cover.
4. Remove lock spring in hub of main drive gear.
5. Insert bolt in shaft and pull out splined drive shaft.
6. Remove water pump drive gears.
7. Remove water pump idler gears.
8. Remove main drive gear. (This gear may be removed from the hub by removing capscrews holding gear to hub.)
9. Using gear puller, remove blower drive gear. (See Fig. 12K.)
10. Remove nuts holding gear housing to blower front end plate.
11. Remove capscrews holding gear housing to lower blower front end plate.
12. Remove castellated nuts and capscrews on inside of gear housing.
13. Protect blower rotor shaft splines with rag, attach hoist and lift accessory drive housing from blower housing.

Install Accessory Drive

1. Oil blower rotor gears.
2. Inspect gasket on accessory drive housing, and renew if damaged. Shellac to accessory drive housing.
3. Protect blower rotor gear splined shaft with rag, attach hoist, lift housing to position on the blower front end plate.
4. Install and tighten castellated nuts and drilled-head capscrews inside drive housing. Lockwire.
5. Place flatwashers, lockwashers and nuts on studs at blower front end plate. Place flat-

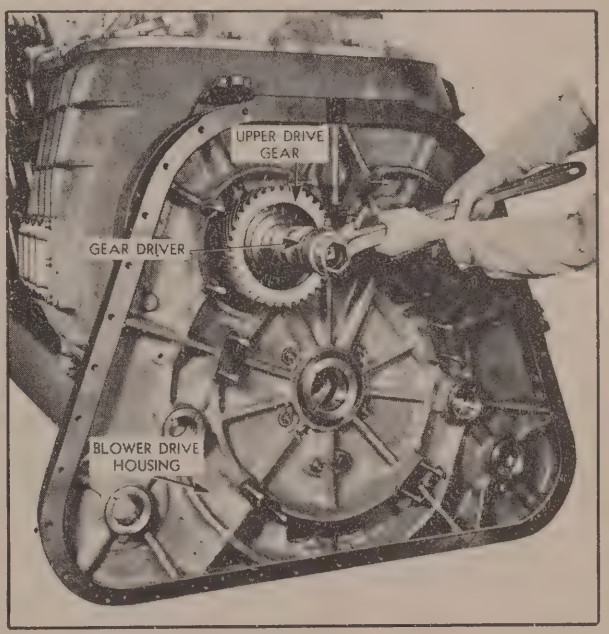


Fig. 13K
Installing Blower Upper Drive Gear

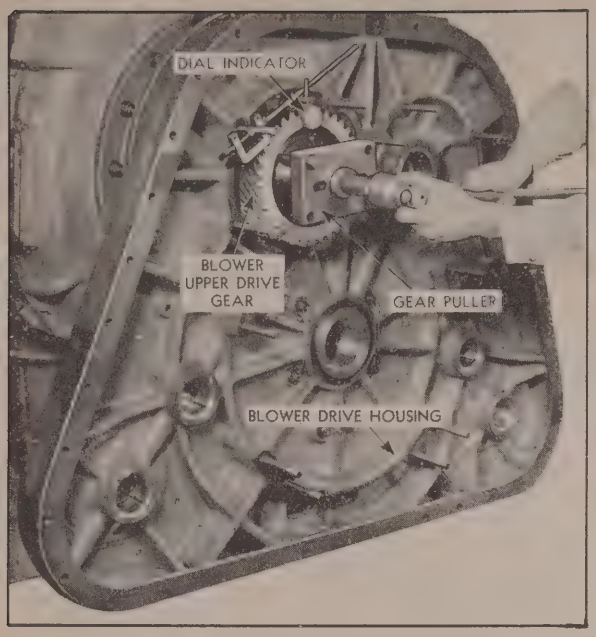


Fig. 14K
Adjusting Upper Drive Gear Clearance

washers, lockwashers and capscrews in lower blower cover. Tighten all evenly.

6. White lead blower rotor shaft spline and place blower drive gear on shaft with concave side of hub toward the housing. Press gear on shaft until it bottoms. (See Fig. 13K.)
7. Attach gear puller and place a dial indicator against the face of the gear. Pul gear back to .005" clearance. (See Fig. 14K.)
8. Oil bearing and install main drive gear.
9. Oil bearings and install water pump idler gears.
10. Inspect spline shafts and gaskets of sea and fresh water pumps and install in housing. Do not tighten.
11. Install pump brackets but do not tighten.
12. Oil water pump drive gears and install on water pump shafts with the serrated end of the hub toward the pump.
13. Tighten water pump attaching nuts and bracket attaching nuts.
14. Oil splines of blower drive shaft and insert through main drive gear hub. Be sure splines are lined up.
15. Insert bolt in end of shaft and push shaft in place.
16. Insert retaining ring.
17. Replace bearing caps in cover, (if previously removed) according to the match numbers on the caps and cover. The numbers must correspond and be at the top to allow lubricating oil to drain from the bearings. The shims that were originally under each cap should be replaced with the caps.
18. Oil gear train and bearings.
19. Attach hoist to cover and lift into position.
20. Place nuts and lockwashers over studs and tighten evenly.
21. Place lockwashers and capscrews around flange in cover and tighten evenly.
22. Install Air Maze and drain line.

Governor and Tachometer Drive

Description. The governor is driven through a set of bevel gears mounted in a housing on the camshaft drive housing. A flanged shaft, bolted to the camshaft gear drives a bevel gear, through serrations in the shaft, which in turn drives a mating gear, the hub of which is serrated to fit the governor drive shaft. The drive bevel gear is enclosed in a carrier which also includes a worm gear for the tachometer drive. The entire assembly is enclosed in a bracket housing bolted to the camshaft drive housing. The unit is lubricated with the oil that flows through the center of the camshaft. The

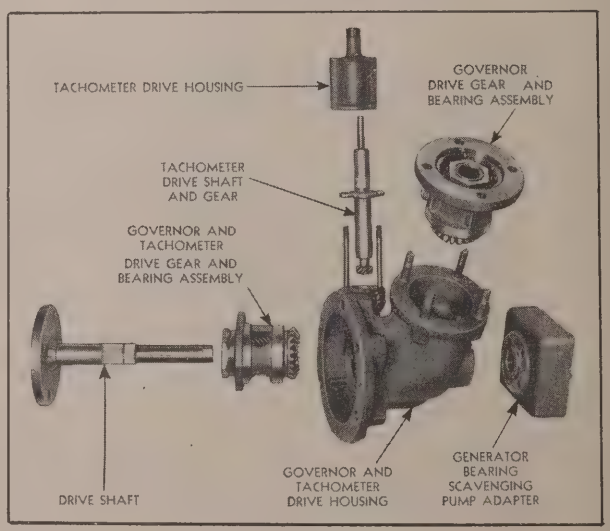

TACHOMETER DRIVE HOUSING
GOVERNOR DRIVE GEAR AND BEARING ASSEMBLY
TACHOMETER DRIVE SHAFT AND GEAR
GOVERNOR AND TACHOMETER DRIVE GEAR AND BEARING ASSEMBLY
DRIVE SHAFT
GOVERNOR AND TACHOMETER DRIVE HOUSING
GENERATOR BEARING SCAVENGING PUMP ADAPTER

Fig. 15K
Governor and Tachometer Drive

generator bearing scavenging pump, if used, is also driven through this assembly.

Maintenance. The drive should be inspected for wear in its bearings and gears. Should the wear become excessive they should be renewed.

Remove Governor and Tachometer Drive.

1. Remove governor. (See Section M.)
2. Disconnect tachometer.
3. Remove capscrews holding drive housing to camshaft drive housing.
4. Pull drive assembly from drive shaft and camshaft drive housing.
5. Remove drive shaft by removing capscrews holding shaft flange to camshaft gear.

Disassemble Governor and Tachometer Drive.

1. Remove generator bearing scavenging pump if used. (See Section P.)
2. Lift governor drive bevel gear and splined sleeve from governor mounting studs.
3. Remove nuts holding tachometer drive housing to bracket and remove housing and tachometer driven worm gear.
4. Remove castellated nuts holding governor bevel gear and tachometer worm gear in housing and remove gear assembly.

Assemble Governor and Tachometer Drive.

1. Reverse disassembly.

Install Governor and Tachometer Drive Assembly.

1. Reverse removal procedure.

Overspeed Trip and Tachometer Drive

Description. The overspeed trip and tachometer drive is the same as the governor and tachometer drive except the drive housing is of the opposite hand. The removal and disassembly is the same as that for the governor and tachometer drive.

CAMSHAFT

Description. Each camshaft consists of two sections which are flanged and bolted together. The shaft sections are accurately centered with relation to each other by means of a pilot on one section which fits in a recess in the other section. There is one bolt in each flanged coupling which is smaller than the driving dowels to insure correct angular relationship between the two sections.

Each section is of the one-piece type with integral case-hardened cams and bearings. The bearing bushings, which are steel backed and babbitt lined, are held in their seats in the campocket with bearing caps. The upper shell is held from turning by a dowel pin in the cap.

There are three cams for each cylinder. The two outer cams operate the exhaust valves, and the center cam operates the injector. Narrower cams, located between the cylinder cam groups operate the air timing valves. These valves, mounted on intermediate covers between the bearing caps, are used only in air started engines.

One end of each camshaft is bolted and doweled to a camshaft driving sleeve. This sleeve is driven from the camshaft gear, which is driven from the crankshaft gear through a train of idler gears, see Section K. The fuel pump is driven from the blower end of one of the camshafts.

The camshaft bearings are lubricated with oil piped from the main manifold through two branch lines to the camshaft gears. The oil flows through a passage in each driving sleeve to the camshaft bore and then through drilled radial holes to each bearing. Oil for lubricating the rocker lever mechanism flows through tubes from the camshaft bearing caps. The campocket serves as a reservoir into which the cams dip, insuring lubrication as soon as the engine is started.

Overflowing oil drains to the oil pan through an external tube at the blower end of each camshaft and through the camshaft drive housing at the other end.

Maintenance. The cams should be inspected for chipped surfaces, cracks and scoring. If the cams are scored to the extent that the valve timing is affected, the camshaft should be renewed. The rocker lever rollers should be checked to see that they rotate freely and are not damaged. The oil passages in the camshafts, driving sleeves, and rocker levers should be inspected for obstructions.

The camshaft bearing bushings should be inspected for cracks, shelling, and excessive wear. The bearing bushings should be renewed if they measure less than 0.1155″ in thickness.

Excessive wear on either the cams or bushings may be caused by operating the engine with insufficient lubricating oil pressure.

Removal of Drive Sleeve.

1. Remove cylinder head cover of cylinder at camshaft drive.
2. Remove camshaft bearing cover.
3. Remove camshaft end cover.
4. Remove nuts holding drive sleeve to camshaft.
5. Remove camshaft drive housing cover. (See Section K.)
6. Remove dowels holding sleeve to camshaft gear.
7. Pull drive sleeves through gear hub from power take off end of engine.

Replacing Drive Sleeve.

1. Line up oil hole in sleeve with oil hole in camshaft gear hub.
2. Reverse removal procedure.

Removing Camshaft.

1. Remove cylinder head covers. (See Section J.)

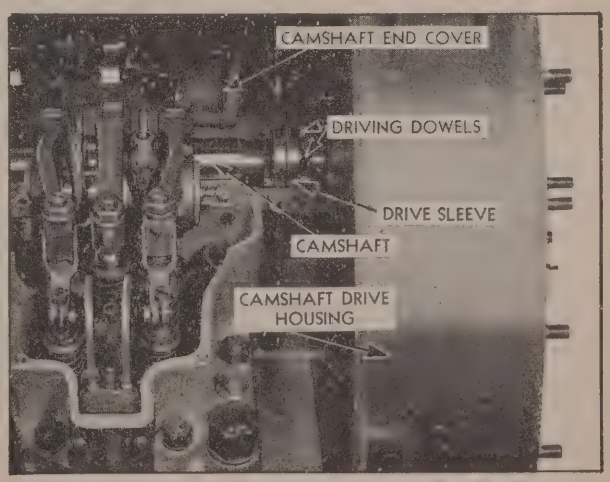


Fig. 1L
Camshaft and Drive Sleeve Connection

2. Remove exhaust elbows and exhaust manifold. Be sure to cover exhaust outlet in cylinder heads. (See Section S.)
3. Remove starting air lines and starting air manifold if used. (See Section U.)
4. Remove rocker arm assembly and valve bridges. (See Section J.)
5. Remove injectors. Be sure to plug injector holes with rags. (See Section N.)
6. Remove camshaft bearing caps.
7. Lift off camshaft intermediate covers.
8. Remove fuel oil pump assembly. (See Section N.)
9. Remove end covers of camshafts at camshaft drive end.
10. Disconnect camshaft drive sleeves.
11. Remove capscrews and bolts holding camshaft end covers at blower end and remove end covers.
12. Using a rope sling, lift out each camshaft. (See Fig. 2L.)
13. Lift out camshaft bearing shells.

Disassemble Camshaft.

1. Remove end caps.
2. Remove driving dowels and bolt holding the camshaft sections together.

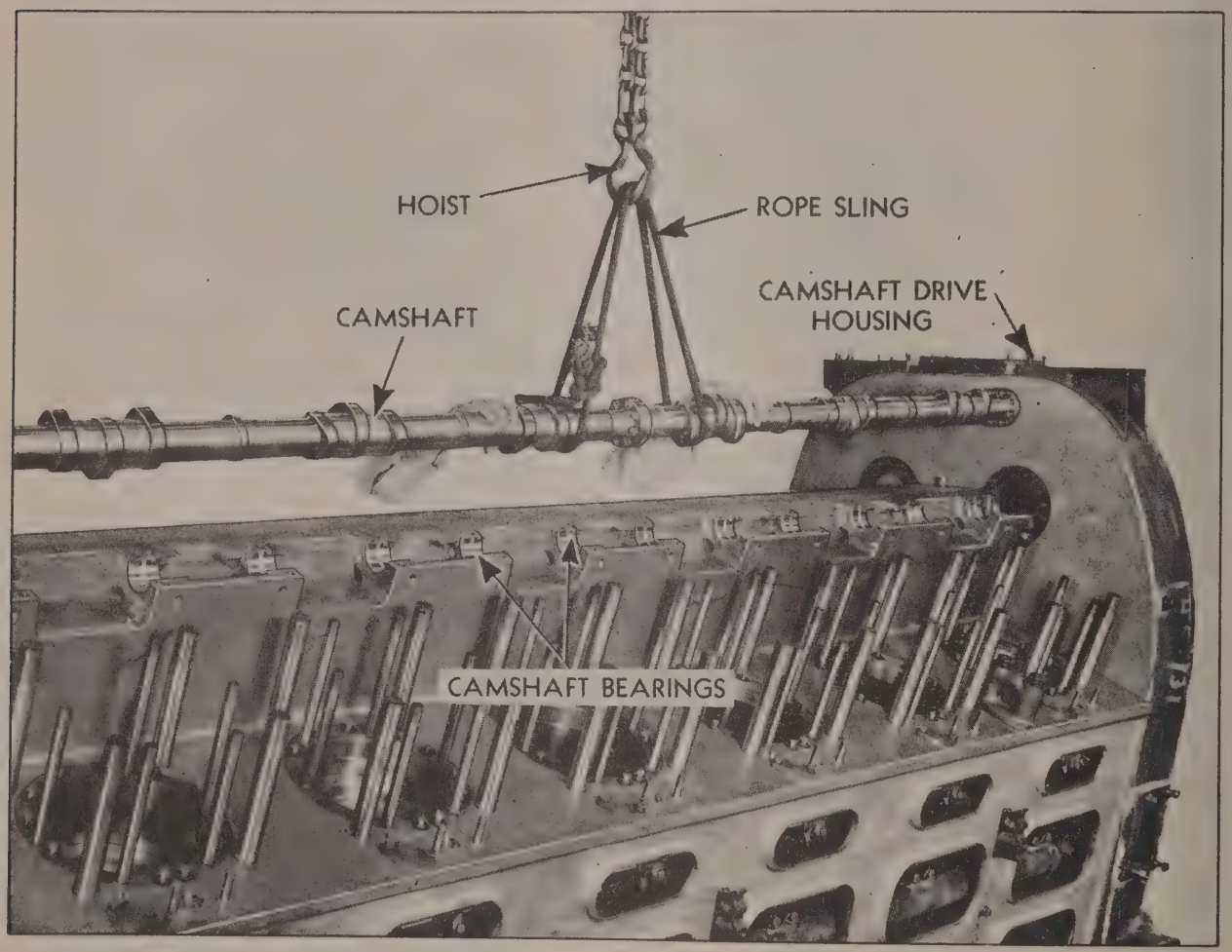


Fig. 2L
Installing Camshaft

Assemble Camshaft.

1. Line up match-marks on mating flanges of camshaft sections and insert driving dowels and bolt. Tighten nuts and lock wire.
2. Install end caps. (Reverse disassembly.)

Install Camshafts.

1. Insert and oil camshaft bearing shells. Be sure tang on bearing shell fits in slot in bearing support.
2. Before placing camshaft in bearing shells, be sure that quick rise on injector cam is on the leading portion of the cam.
3. Balance of installation is reverse of removal procedure.

ENGINE CONTROL

Description. The engine speed is held uniform for any setting of the governor, which is located at the power take-off end of the engine.

The movements of the governor power mechanism are transmitted through lever and link connections to an injector control shaft located in a pocket just below the upper deck plate of each cylinder bank. Each fuel injector rack is connected to a control shaft lever through a slip-joint link. A micrometer adjusting screw on this link is used to increase or decrease the amount of fuel injected into the combustion space.

A spring in the slip-joint link is preloaded to limit the force that can be applied to move the injector control rack. Under any load less than the predetermined load, the spring holds the link to its correct length. The unusual feature in this slip-joint link is that the spring is compressed when the link is either shortened or lengthened by a load greater than the predetermined load. Any movement of the slip-joint link when the injector is heavily loaded, during the pumping part of the stroke, compresses the slip-joint spring; but at the end of the high pressure period, it instantly turns the plunger into the correct relation to the other injector plungers. When the control rack in one injector is stuck, the compression of the spring in the slip-joint link connected to that injector allows normal operation of the other injectors.

A hand control lever is used for manual control when starting or stopping the engine and must be latched in the "Run" position when the engine is turned over to governor control.

When the governor or any part of the injector control system is replaced with new parts, the governor power piston should be linked in the correct relation to the injector rack travel as described under "Engine Adjustments," in Section E.

After the load has been placed on the engine, the exhaust temperatures are adjusted with the micrometer screws as explained in Section E.

Maintenance. If, after the engine and all parts are up to normal temperature, the governor should hunt excessively and this cannot be corrected with the compensating needle valve, the control linkage should be inspected for binding as described under "Engine Adjustments," in Section E. If no binding is evident in the control linkage, the governor must be removed and thoroughly cleaned.

Remove Injector Control Shaft.

1. Remove control shaft covers.
2. Disconnect injector control link from control shaft levers.
3. Remove bolts and castellated nuts connecting the sections of the shaft.
4. Starting at rear of engine remove first section.
5. Loosen micro-adjustment connections on shaft.
6. As shaft sections are withdrawn, the micro-adjustment connections will slide off.
7. Remove shaft bearings, 2 capscrews and lockwashers.

Install Injector Control Shaft.

1. Reverse removal.

Governor

Description. The engine speed is controlled by a self-contained hydraulic governor, which consists of three essential elements: a speed sensitive element; a power mechanism for actuating the fuel injector control racks on the engine; and a compensating mechanism, which is the stabilizing element.

The speed sensitive mechanism consists of a pair of flyballs and a speed adjusting spring which balances the centrifugal force resulting from the flyball rotation. When a change in engine load takes place, a momentary speed change results. This speed change brings about a change in the centrifugal force of the flyballs, with the result that the flyballs assume a slightly different position until perfectly balanced against the speed adjusting spring. As the flyballs move away from their central position, due to a change in centrifugal force, they raise or lower the pilot valve proportionally. This allows the oil to flow, under pressure, to and from a double acting power cylinder, causing the power piston to move. The motion of the power piston is transmitted through a linkage to the fuel injector racks on the engine. In order to prevent over-travel of the fuel injector racks, the compensating mechanism acts on the bottom of the governor pilot valve in a direction opposite to the movement imparted to the pilot valve by the flyballs.

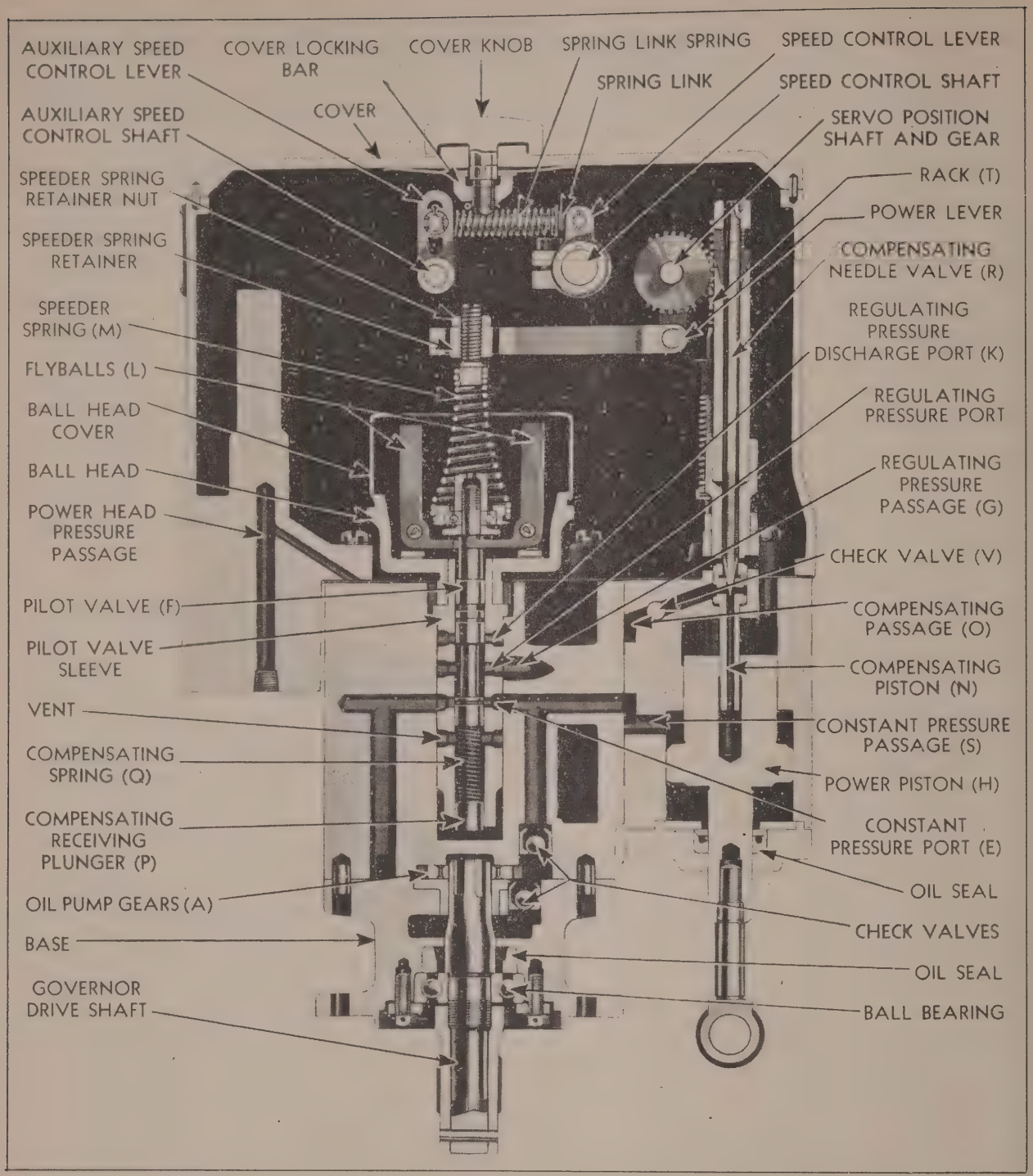


Fig. 1M
Governor Assembly

The power piston, in moving, causes oil to act on a small receiving compensating plunger attached through a spring to the lower end of the pilot valve. Thus, for any movement of the power piston, a temporary force is exerted on the receiving compensating plunger in proportion to the amount of power piston movement. A needle valve, vented to the governor sump, allows the oil between the receiving compensating plunger on the pilot valve and the transmitting compensating plunger in the power cylinder to flow to or from the governor sump. Thus, a short time after the power piston has moved, the restraint placed on the pilot valve by the receiving compensating plunger is dissipated. In other words, this compensation is a temporary counteraction of the action initiated by the flyballs proportional to the amount of power piston movement.

If the compensating needle valve is opened too much, the governor will become unsteady, and cause the engine to hunt. If the compensating needle valve is closed tight, the engine will return to normal speed very slowly after a load change.

The compensating spring which connects the receiving compensating plunger to the lower end of the pilot valve allows the pilot valve to respond promptly to any change in the centrifugal force of the flyballs. The pilot valve, compensating spring, and receiving compensating plunger all rotate inside a stationary valve sleeve, which relative rotation eliminates the possibility of binding due to foreign matter in the oil, and assures that the pilot valve is free to respond to the slightest change in speed. During normal, steady operation, there is no compression or tension in the compensating spring because oil seeps to and from the sump through the compensating needle valve and allows the compensating plunger to move until the compensating spring is completely unloaded.

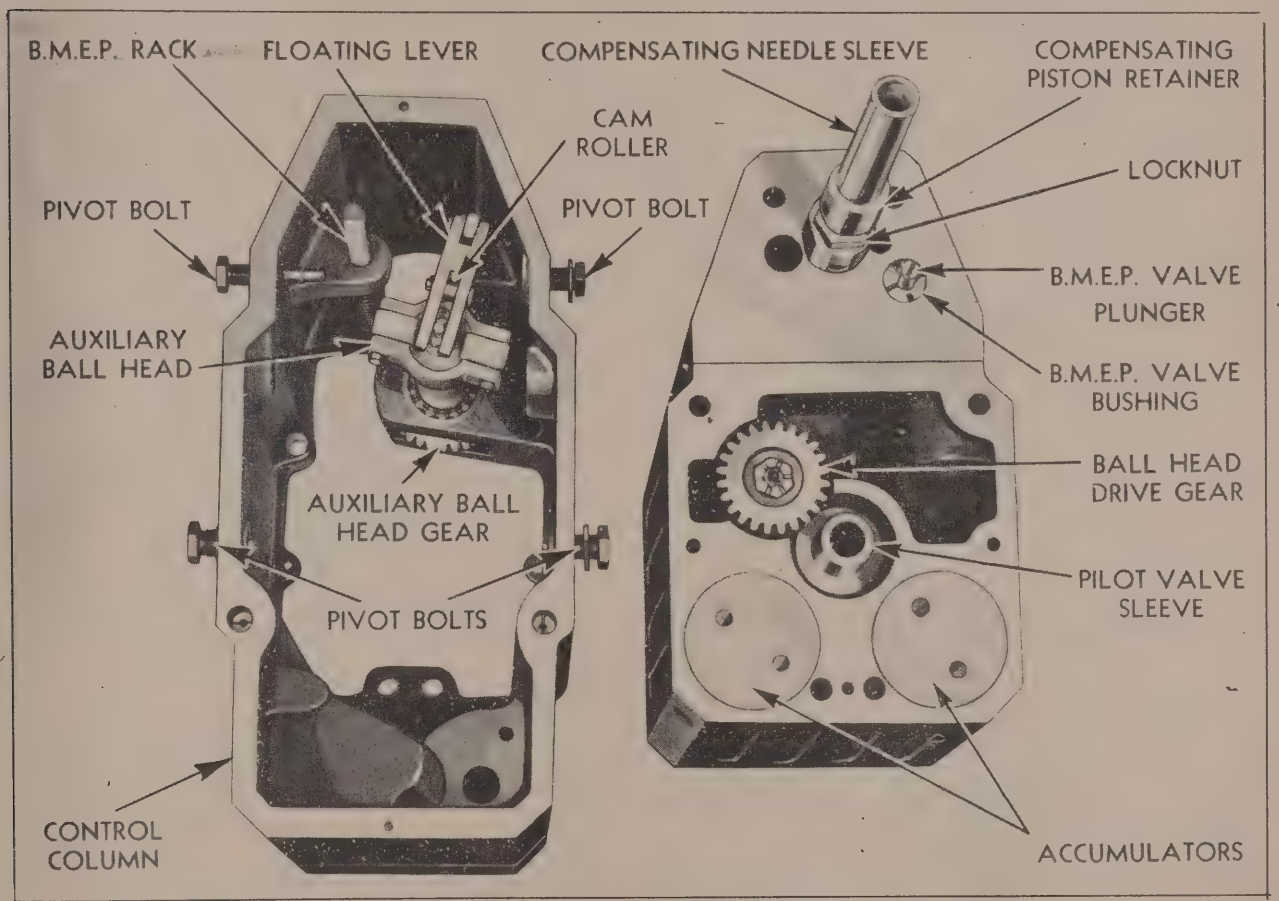


Fig. 2M
Governor Control Column Assembly

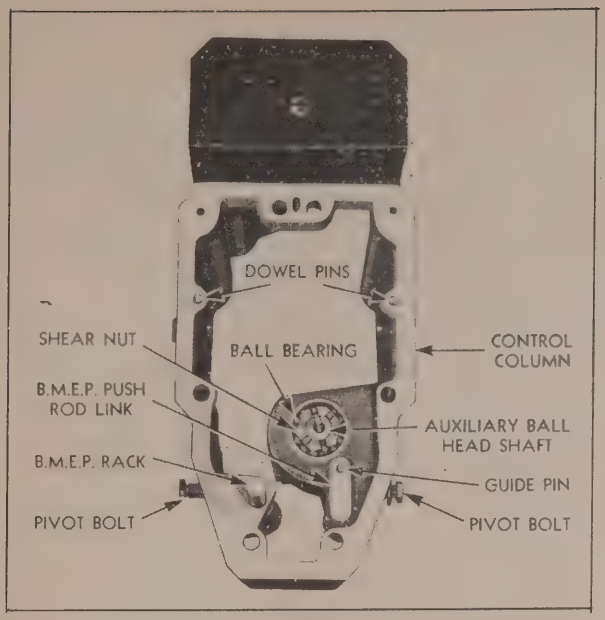


Fig. 3M
Bottom View of Governor Control Column

Whenever the pilot valve is moved upward as the result of a speed increase, the power piston moves to shut off fuel, and, at the same time, to displace oil in the compensating passage. This causes a downward force to be exerted on the receiving compensating plunger or in a direction opposite to the initial pilot valve movement. Likewise, a decrease in speed resulting from an increase in load, causes the pilot valve to move downward causing the power piston to increase the fuel and also force the receiving compensating piston upward against the downward movement of the pilot valve. The sequence of operation from the time a load change causes a speed change until the power piston has moved to the correct fuel setting and until the speed is again stabilized to normal, requires about one second.

Governor Operation

Fig. 11M, Sheet 1, Cut 1, shows the governor operating with the engine at normal speed. The centrifugal force on flyballs (L) is balanced by the compression of speeder spring (M), and the flyballs are in their normal position holding pilot valve (F) in its central position.

The regulating pressure discharge port (K) is closed by the pilot valve (F), trapping oil in regulating pressure passage (G). Oil under pressure from the governor pump is acting on constant pressure area (I), but since the oil is trapped in regulating pressure passage (G), the power piston (H) is unable to move in either direction, thus holding the engine speed constant.

Fig. 11M, Sheet 1, Cut 2, shows governor acting in response to a decrease in engine speed. The decrease in engine speed causes a decrease in the centrifugal force acting on flyballs (L) allowing speeder spring (M) to move the flyballs in, thus lowering pilot valve (F). Lowering the pilot valve opens constant pressure port (E) to regulating pressure passage (G) allowing oil under pressure from the governor pump to be admitted to both constant pressure passage

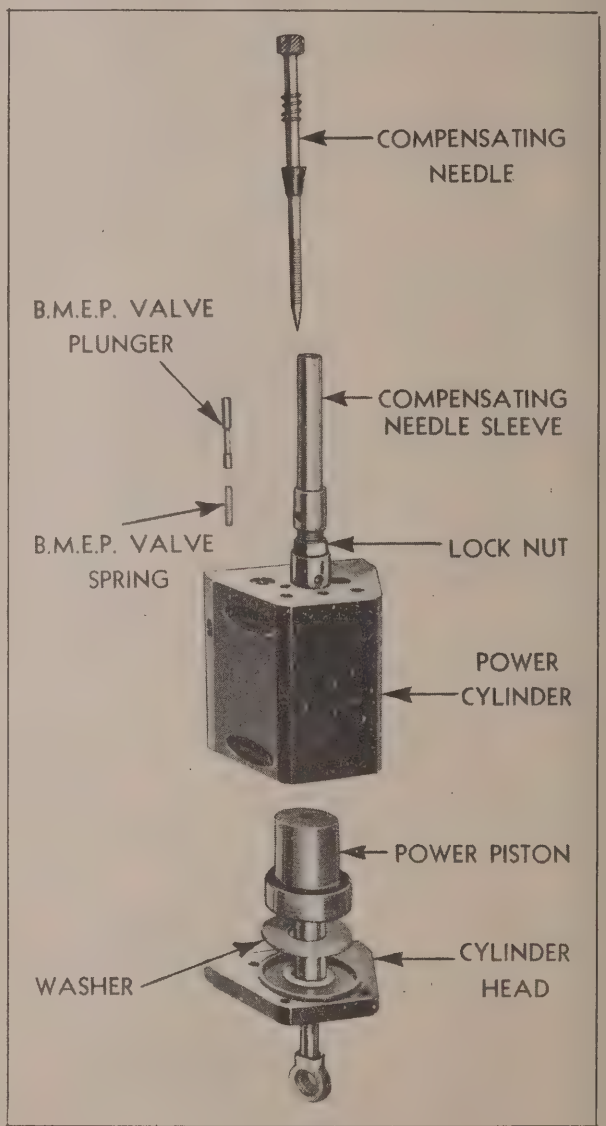


Fig. 4M
Governor Power Piston

(S) and regulating pressure passage (G). Thus constant pressure area (I) and regulating pressure area (J) are under the same oil pressure. However, as area (J) is larger than area (I), the total force working against area (J) is greater than the total force working against area (I). Therefore, the power piston (H) will move in a direction to increase the fuel supplied to the engine, thus increasing the speed of the engine.

When the power piston moves in, oil is displaced in the trunk end of the power piston by the transmitting compensating plunger (N). The oil displaced flows through compensating passage (O) and pushes compensating receiving plunger (P) upward. The compensating receiving plunger (P) is connected to the pilot valve (F) by compensating spring (Q). Since the compensating receiving plunger (P) is moving in a direction opposite to that of the pilot valve (F) it resists the downward movement of the pilot valve and prevents the pilot valve from over-shooting. A needle valve in the compensating passage allows a slight seepage of compensating oil from the compensating passage to the governor sump so that the compensating oil will act only temporarily on the compensating receiving plunger. The needle valve must never be closed tight.

Fig. 11M, Sheet 1, Cut 3, shows governor acting in response to an increase in engine speed. The increase in the engine speed causes an increase in the centrifugal force acting on flyballs (L) overcoming the compression in speeder spring (M) forcing the flyballs out, thus raising pilot valve (F). The pilot valve (F) in rising opens regulating discharge port (K) relieving the pressure in regulating pressure passage (G). Since oil under pressure from the governor pump flows around the pilot valve (F) through constant pressure port (E) into constant pressure passage (S), pressure is acting on constant pressure area (I) to move power piston (H) in the fuel off direction decreasing the engine speed.

When the power piston moves down, its movement draws oil from compensating passage (O) through compensating plunger (N). This action pulls compensating receiving plunger (P) downward. Since the compensating receiving plunger (P) is moving in a direction opposite to that of the pilot valve (F) it resists the upward movement of the pilot valve and prevents the pilot valve from overshooting. The needle valve in the compensating passage allows governor sump oil to be drawn into the compensating passage so that the compensating oil will act only temporarily on the compensating receiving plunger. The needle valve must never be closed tight.

As shown in Fig. 11M, Sheet 2, Cut 4, gear pump (A) draws oil from the governor sump and forces it to the spring-loaded accumulators (B). The accumulator piston (C) moves up under the pressure of the oil until the bottom of the accumulator piston (C) opens unloader port (D), allowing the excess oil

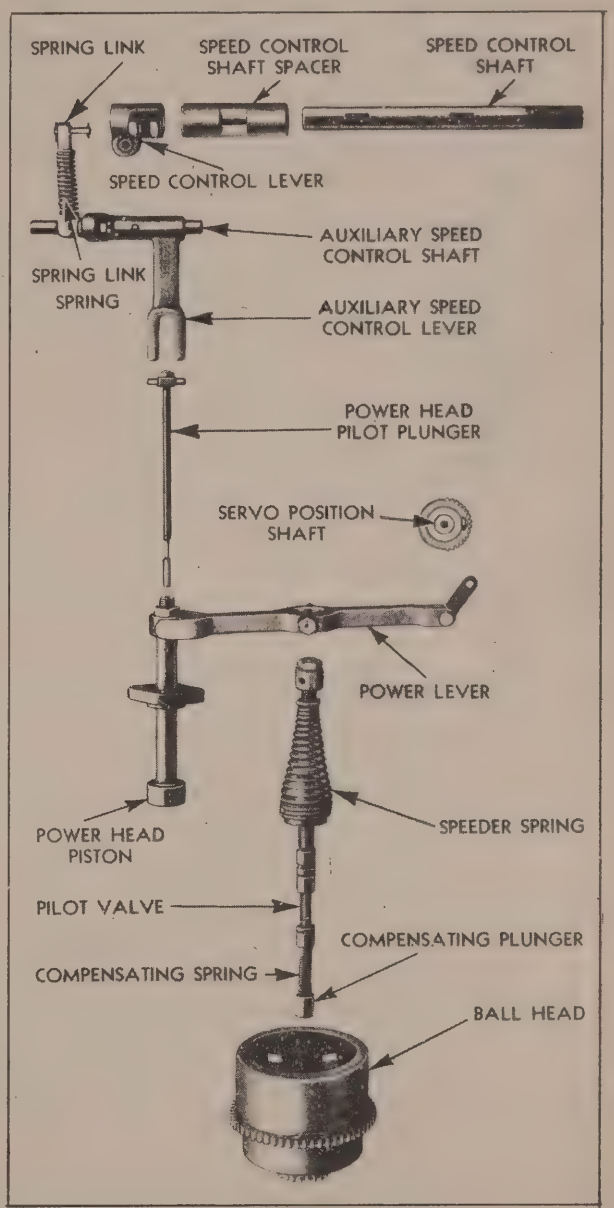


Fig. 5M
Governor Control Mechanism

to escape to the sump. Thus a constant hydraulic pressure is maintained in the governor system. Check valves in the oil pump are arranged so that the governor drive shaft may be rotated in either direction. Pressure oil from the accumulators (B) flows around pilot valve (F) through constant pressure port (E) into constant pressure passage (S) to the constant pressure area (I) on power piston (H). Constant pressure passage (S) and area (I) are under pressure at all times.

Manual Emergency Shut-down. Manual emergency shut-down of the engine (aside from the hand throttle lever) is accomplished by pressing down the button on top of the governor and holding the button down until the engine stops. Pressing the button opens the B.M.E.P. valve (U) allowing oil under pressure to by-pass to the compensating oil passage (O) and at the same time cuts off the needle valve duct so that pressure will not be dissipated through the needle valve into the sump. The pressure under compensating receiving plunger (P) forces the pilot valve upward which causes the servo-piston to move in the "fuel off" direction and stop the engine.

Governor Power Head. The power head is a power relay that enables a very small force to accurately control a larger force. Its purpose in the governor is to reduce and keep constant the force required to turn the governor control shaft for changes of regulating speed.

An auxiliary speed control lever is pivoted at the upper end of the pilot plunger and connected by a mechanical linkage to the governor control shaft. As the governor control shaft is rotated by the governor receiver motor to move the pilot plunger down, port "D" is uncovered and the oil trapped under the piston flows out and up the three flat sides of the pilot plunger to the governor sump as the oil pressure acting on area "B" forces the piston downward. The piston will continue to move downward until the port "D" is again covered by the pilot plunger and prevents any more oil from flowing out from under the piston. The remaining oil trapped under the piston holds the piston against the downward force of the oil acting on area "B." As the governor control shaft is rotated by the governor receiver motor to move the pilot plunger up, port "C" is uncovered, and pressure oil flows into the lower part of the cylinder and acts on piston area "A." Since area "A" is larger than area

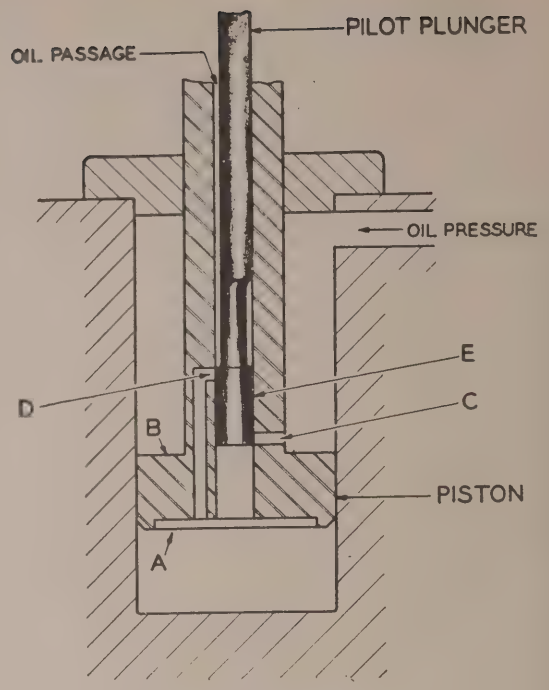


Fig. 6M
Governor Power Head

"B," the oil pressure will force the piston upward until the pilot plunger again covers port "C," stops the flow of oil into the lower part of the cylinder, and stops the piston.

Brake Mean Effective Pressure Limiter. The governor is provided with a brake-mean-effective-pressure-limiter. Its purpose is to shut down the engine due to overload.

A floating lever, operated from a cam through the movements of the power piston, controls a valve which by-passes oil under pressure into the compensating duct and at the same time cuts off the compensating needle valve so that the pressure will not be dissipated to the governor sump. The pressure oil acts on the compensating receiving plunger forcing the pilot valve upward, resulting in movement of the power piston in the fuel off direction. The auxiliary set of flyballs allows the B.M.E.P. Limiter to go into operation at a predetermined overload for any speed setting of the governor. The operation of the B.M.E.P. Limiter is automatic and when the overload is removed it goes out of operation.

Operation. As shown in Fig. 11M, Sheet 2, Cut 4, when the engine speed drops due to overload, the main flyballs move in, the pilot valve lowers and

moves the power piston upward in the "Fuel on" direction. As the power piston moves upward the rack (T) rotates the B.M.E.P. cam, lowering the fulcrum point of the floating lever. At the same time as the main flyballs move in, the auxiliary flyballs move in, raising the free end of the floating lever, and forcing the other end of the floating lever downward, opening the B.M.E.P. valve (U).

This action permits pressure oil to enter the compensating passage (O) and force the compensating receiving plunger (P) and the pilot valve upward, resulting in movement of the power piston downward. When the pressure is released by the B.M.E.P. valve, it forces a check valve, (V), that isolates the compensating needle valve (R) and prevents the oil pressure from dissipating to the governor sump.

Maintenance. Unless the oil in the governor becomes contaminated by water, etc., it is not necessary to change oil more than once a year, because the governor ballhead, in rotating at a high speed, acts as a centrifuge and all ordinary heavy foreign matter in the oil becomes deposited on the inner periphery of the ballhead. Every three months the ballhead should be removed and washed in carbon tetrachloride to remove this dirt deposit. The oil level should be kept about level with the joint between the governor power case and the speeder column. If the oil should be a little high and churn to a froth from ballhead rotation no particular detrimental action will result, as this governor is not sensitive to air bubbles in the oil. Any good grade of neutral mineral lubricating oil, such as is used in the engine, may be used in the governor.

The joints between all exposed parts of the governor are provided with thin packing except the joint between the power case and the governor base. This joint has no packing but is lapped oil-tight so that the .001" end clearance of the oil pump gears can be maintained. Should this joint ever be taken apart, its faces must be carefully cleaned before reassembling, because any particles left between the surfaces will cause oil leakage.

Remove Governor from Engine.

1. Disconnect governor speed control link.
2. Remove clevis pin from governor link and power piston tail rod connection.
3. Remove four nuts from governor base.
4. Swing quadrant arm up until the last tooth on the quadrant is meshed with the governor receiver motor. Mark these mating teeth. Lift governor straight up, being careful not to damage spline shaft.

Governor Disassembly.

1. Remove governor cover by turning knurled knob on top of governor and lifting cover off.
2. Remove lowest slotted pipe plug in body of governor to drain oil.
3. Remove cotter pins from speed control lever pin and remove pin.
4. Back out screw pivots from each end of the auxiliary speed control shaft. It is not necessary to remove the screw pivots from speeder column. Lift out auxiliary speed control shaft, auxiliary speed control lever, and spring link as an assembly.
5. Scribe a mark on the speed control shaft opposite the split in the quadrant arm. Remove the quadrant arm.
6. Loosen Allen setscrew in speed control lever. Push splined end of speed control shaft through speed control lever, rotate speed control shaft spacer so that key in lever will slide into keyway in spacer. When key appears in slot of spacer, the key must be removed. The speed control shaft can then be removed, allowing the speed control lever and spacer to be removed.
7. Lift out power head pilot plunger.
8. Back out two pivot bolts holding speeder spring retainer nut to power lever until nut is free. It is not necessary to remove the pivot bolts.
9. Remove nuts on top of power head piston and lift off top half of pivot pin bearing.
10. Back out pivot bolts on each end of servo position shaft. It is not necessary to remove the pivot bolts from the speeder column. When shaft is free, lift out shaft and power lever.
11. Unscrew compensating needle several turns.
12. Carefully lift out the speeder spring, pilot valve and compensating spring and plunger.
13. Lift out ballhead.
14. Remove 6 screws holding control column to power case. Lift off column, being careful not to damage gasket or compensating needle sleeve or needle.
15. Remove cotter pin and shear nut from bottom of auxiliary ballhead shaft.

16. Tap on end of auxiliary ballhead shaft until auxiliary ballhead assembly can be removed from the control column.
17. Lift out auxiliary ballhead gear and gently drive out lower auxiliary ballhead ball bearing. Upper bearing will remain on ballhead.

Governor Assembly.

1. Install auxiliary ballhead gear.
2. Line up Woodruff key in auxiliary ballhead with slot in gear and install auxiliary ballhead and upper bearing assembly. Be sure to put pressures on outer race of ball bearing.
3. Install lower ball bearing and shear nut; tighten the cotter pin.
4. Place new gasket on power case and install control column assembly.
5. Install main ballhead assembly.
6. Carefully install pilot valve and speeder spring assembly.
7. Install servo position shaft and power lever assembly.
8. Install power head pivot pin bearing and nuts.
9. Insert speed spring retainer pivot bolts and tighten.
10. Install power head pilot plunger.
11. Install speed control shaft in governor case and into spacer. Install Woodruff key in shaft.
12. Place speed control lever in position, align key slot with key in speed control shaft and tighten Allen setscrew.
13. Place auxiliary speed control lever and spring link assembly on shaft and install in governor. Be sure pin in power head pilot plunger enters slot in auxiliary speed control lever. Tighten pivot bolts.
14. Install speed control lever pin and cotter pin.
15. Install drain plug and cover.

Installing the Governor.

1. Align splines on governor shaft with splines in governor drive on the engine and install governor. Before tightening nuts, make certain that the governor is properly seated on the governor drive housing.
2. Install clevis in governor power piston tail rod.

Note: If installing a new governor, the needle bearing must be removed from the old governor power piston tail rod and installed in the new governor.

3. Mesh the marked teeth on the quadrant segment and the receiver motor pinion. (See Step 4 under "Remove Governor from Engine.")

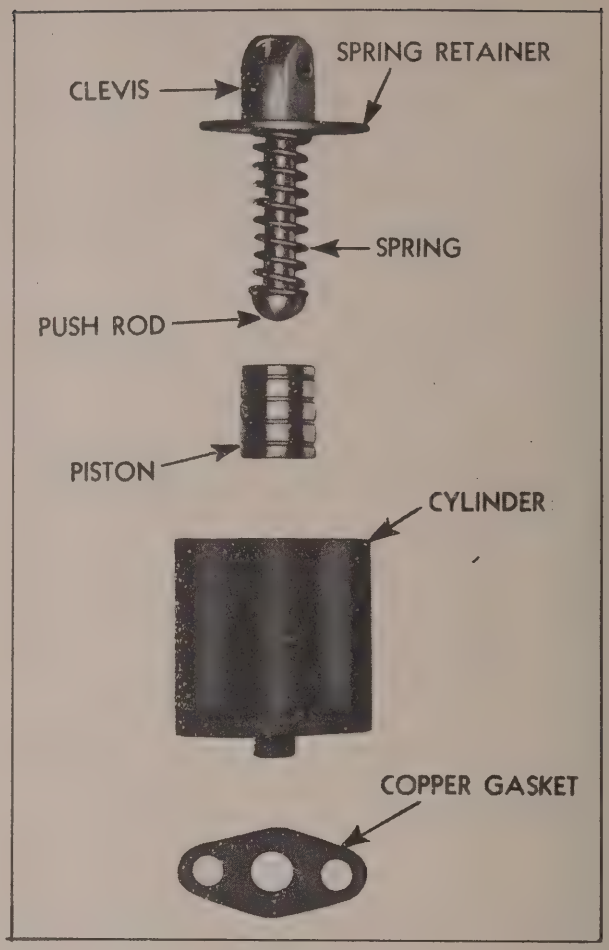


Fig. 7M
Overspeed Shutdown Servo Motor

Overspeed Governor

Description. A hydraulic overspeed governor is provided to shut down the engine if, for any reason, the engine speed exceeds a predetermined safe operating speed. It is located at the generator end of the engine and is driven through an angle gear drive from one of the camshafts.

The overspeed governor contains a positive displacement gear pump which forces high pressure oil through a tube to the top pipe in the multiple manifold assembly on each cylinder bank. The oil flows from the manifold, through tubing, to a

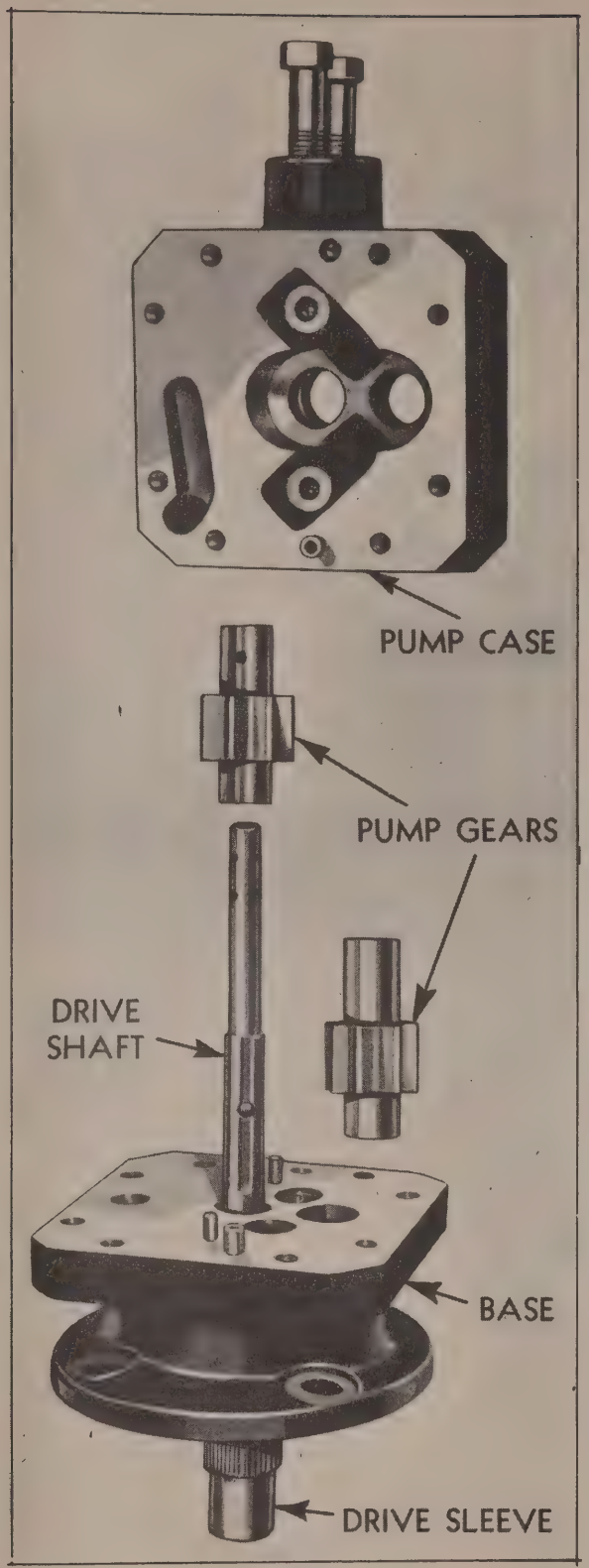


Fig. 8M
Overspeed Governor Base and Pump Case

passage in each cylinder head and under the piston of a servo motor attached to each cylinder head. The servo motor actuates a lever which holds the injector rocker arm down so that the injector is at the bottom of its stroke, preventing the injector from operating. The pressure in the system is released by pressing down the knob on the top of the overspeed governor.

Remove Overspeed Governor.

1. Disconnect oil lines.
2. Remove nuts from hold-down studs.
3. Lift overspeed governor carefully from drive bracket.

Install Overspeed Governor.

1. Align splines in drive shaft with drive gear and lower in position.
2. Install hold-down nuts.
3. Install oil lines.

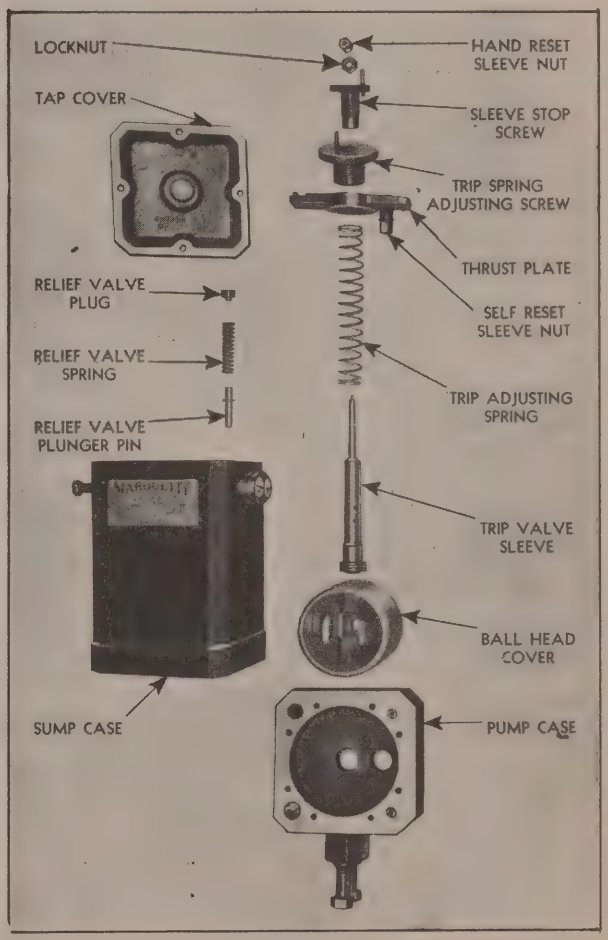


Fig. 9M
Overspeed Governor Column and Valve

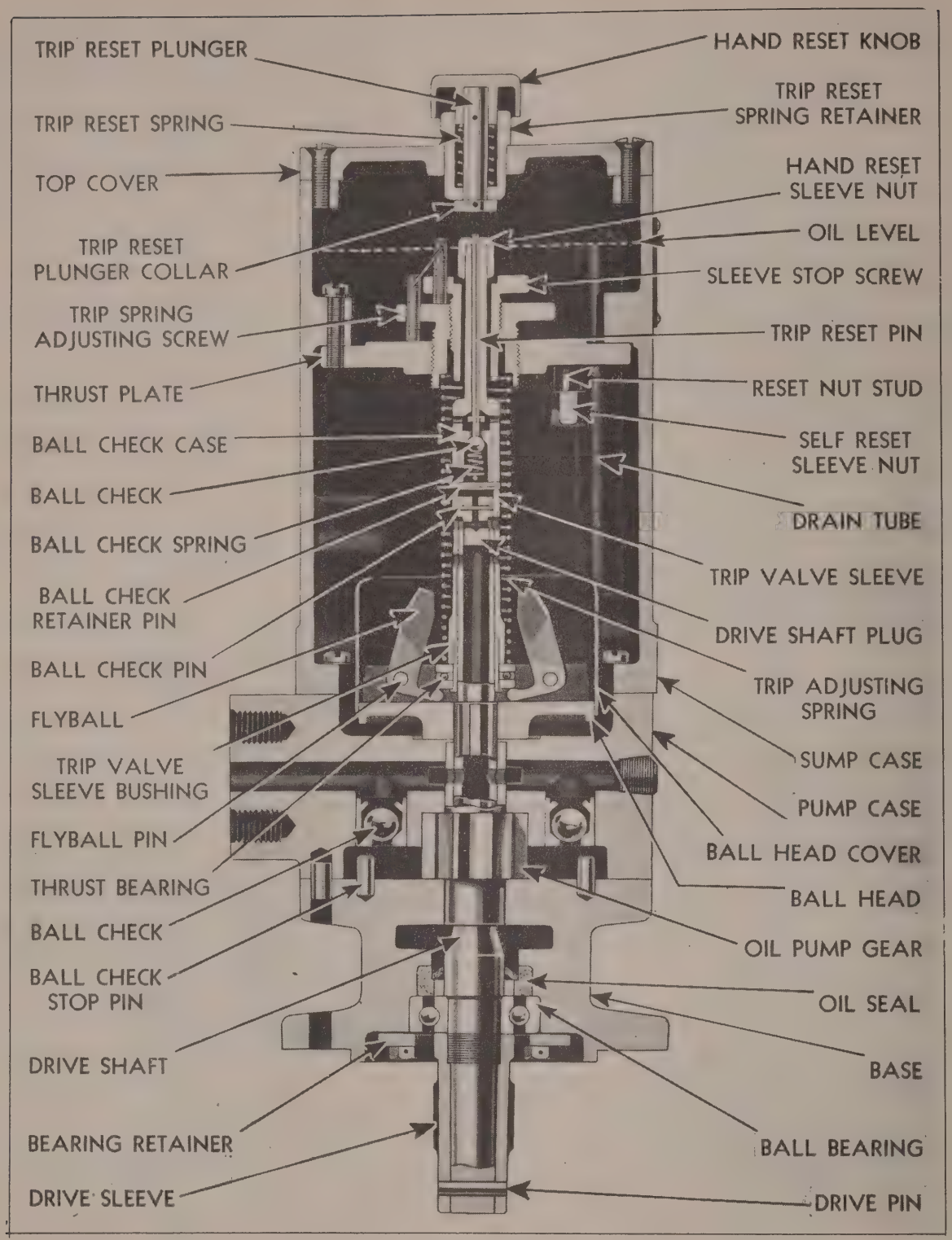


Fig. 10M
Overspeed Trip

Fig. 11M
Sheet 1

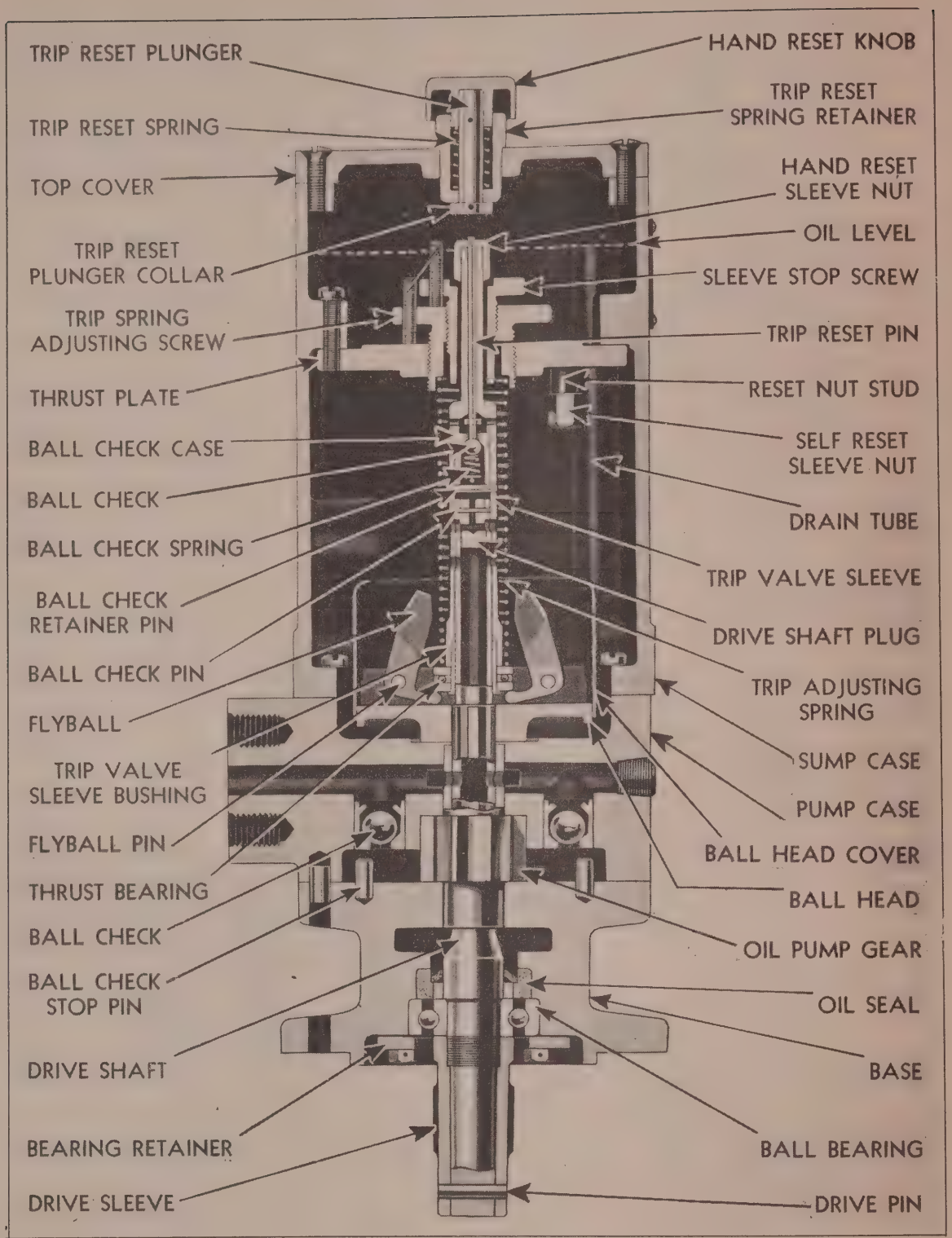
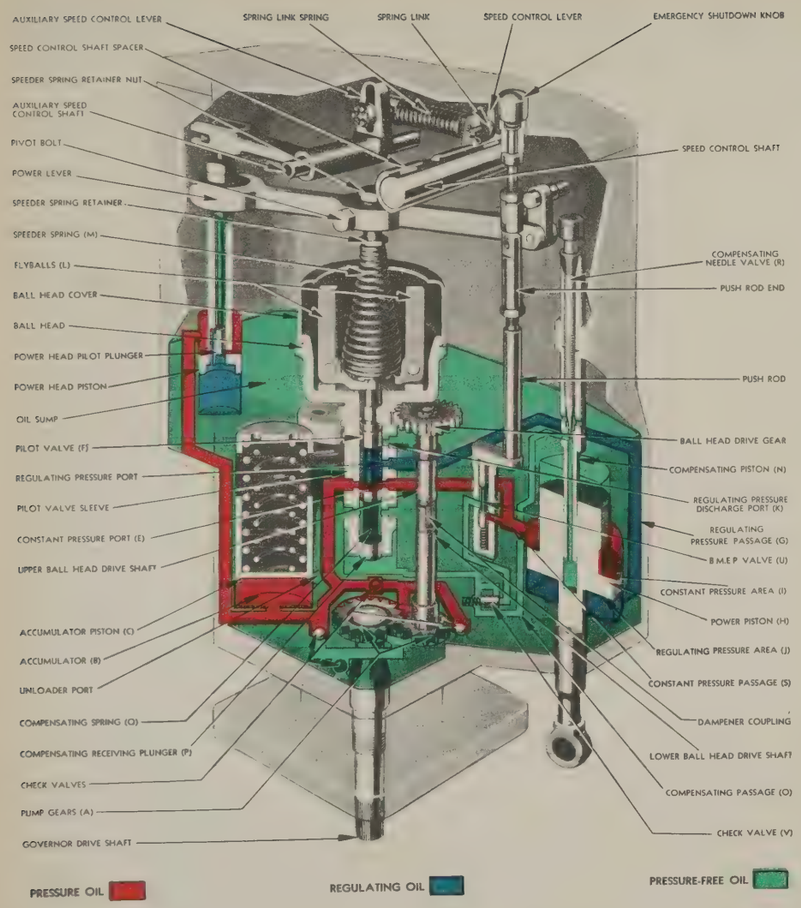


Fig. 10M
Overspeed Trip



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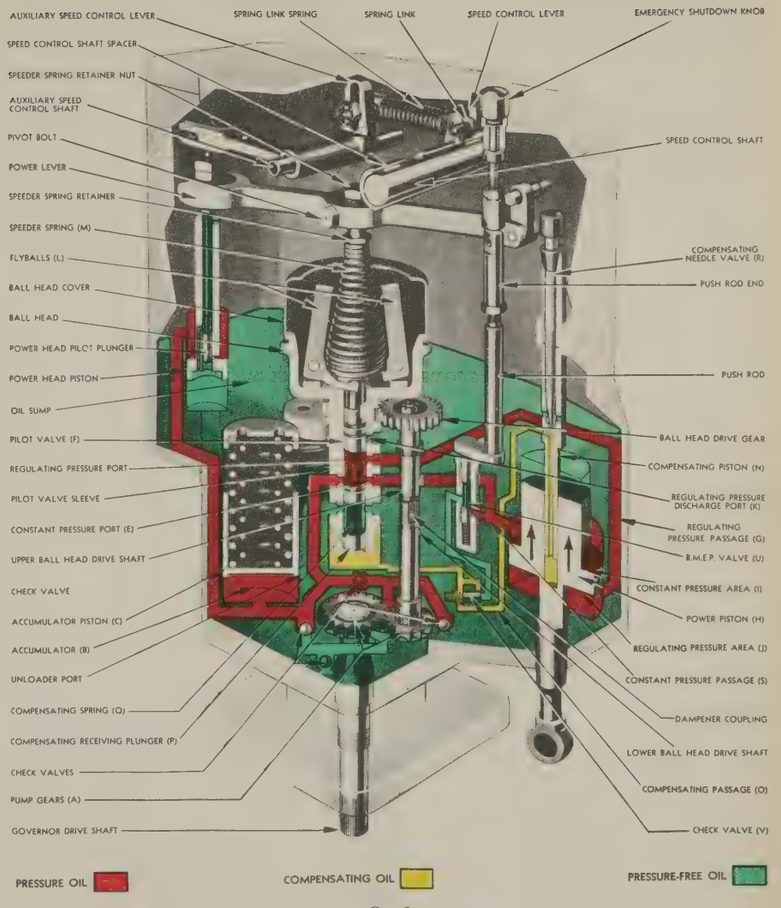

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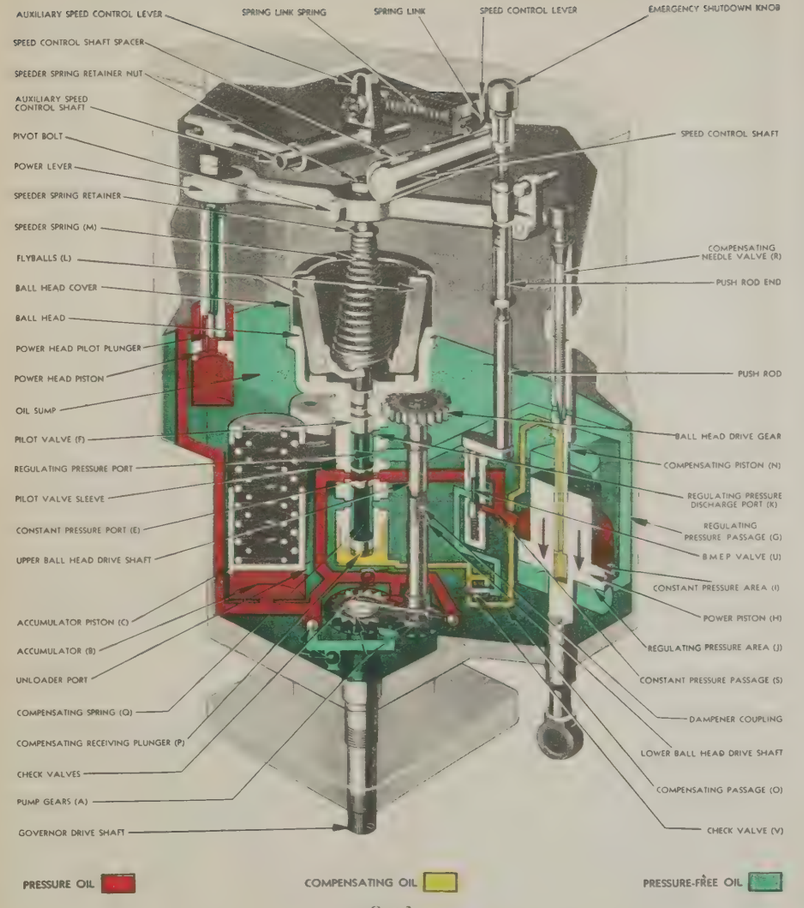

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Fig. 11M Sheet 1
Governor Operation

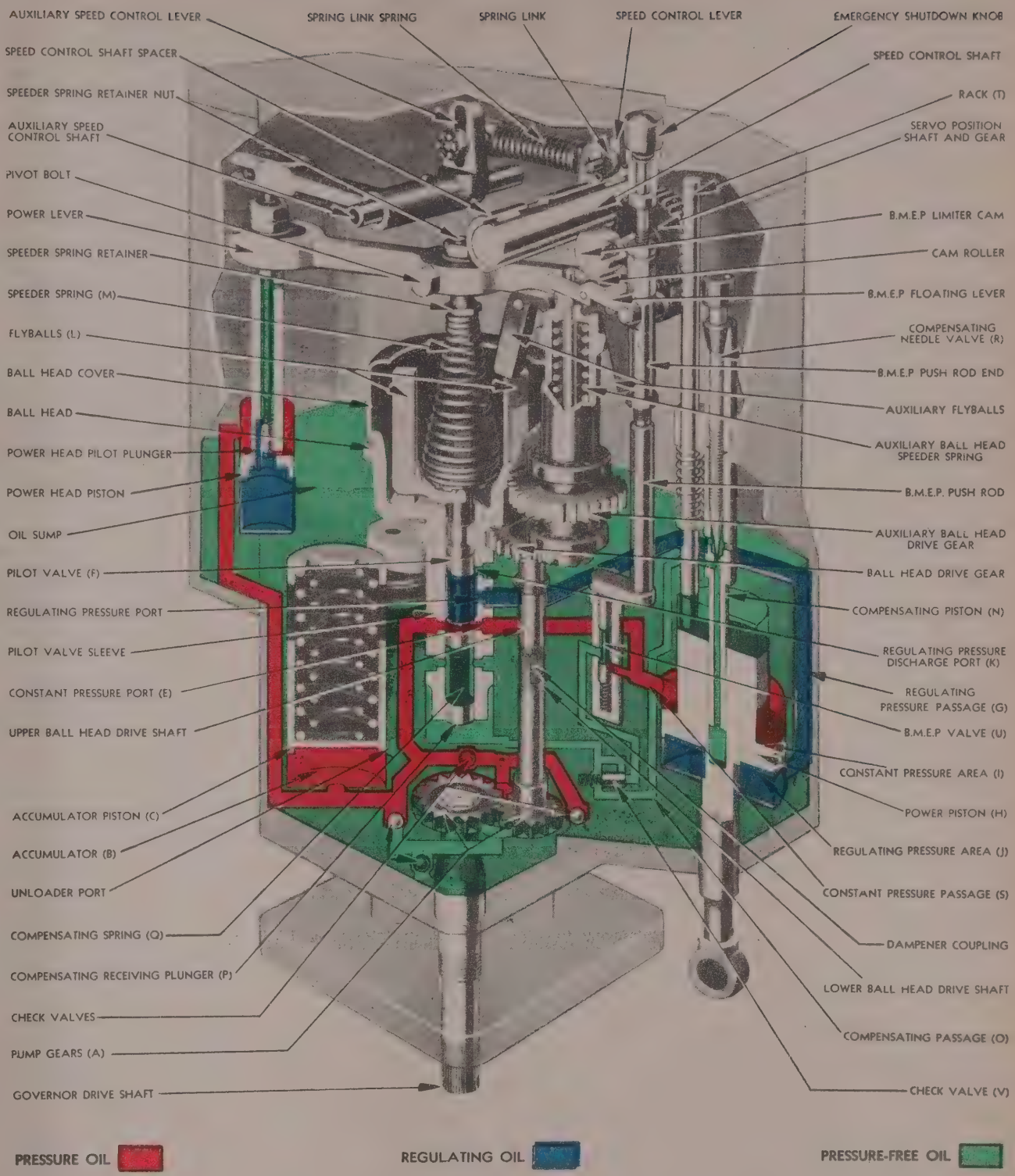

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Fig. 11M
Sheet 2

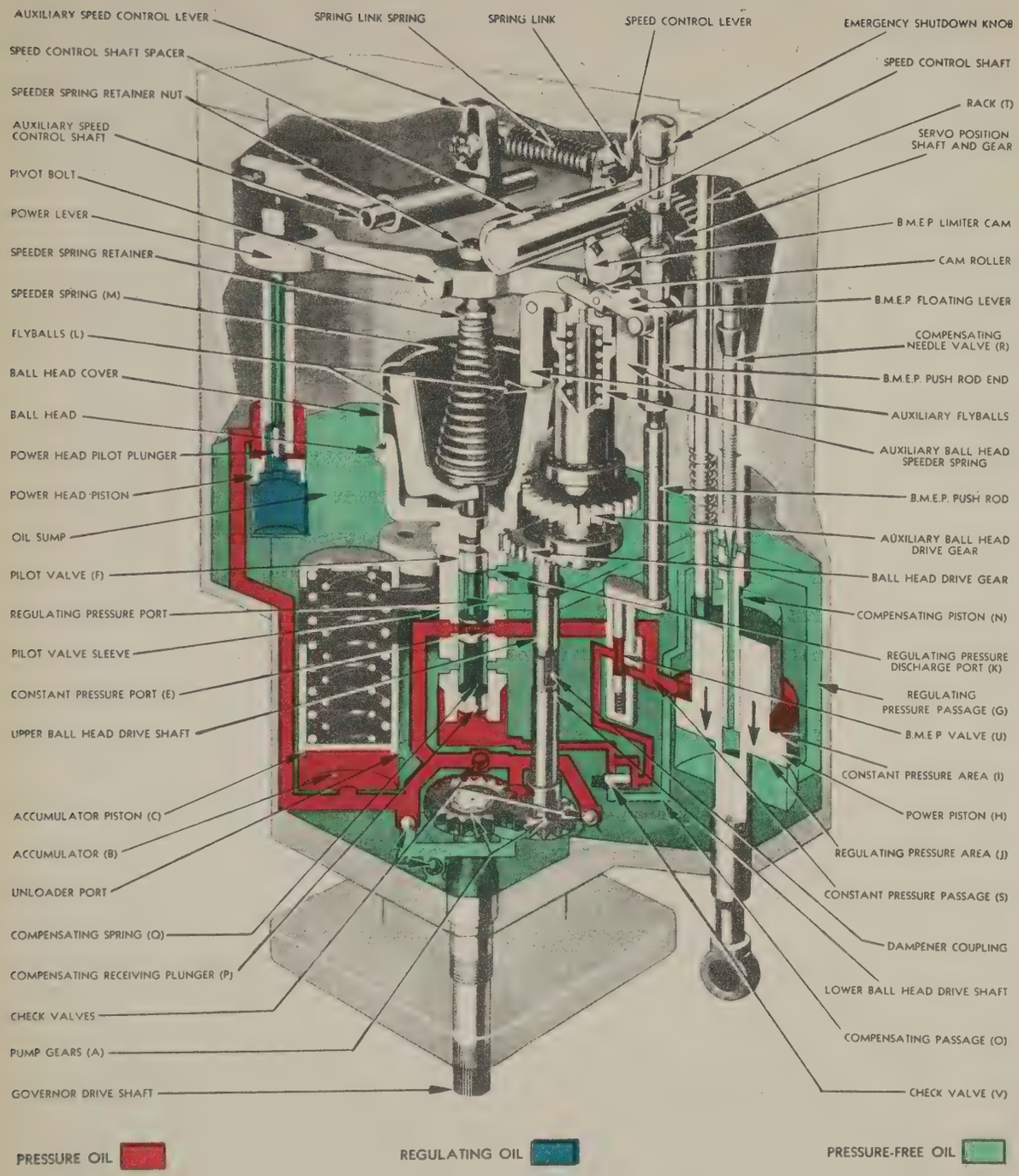

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Fig. 11M —Sheet 2
Governor Operation

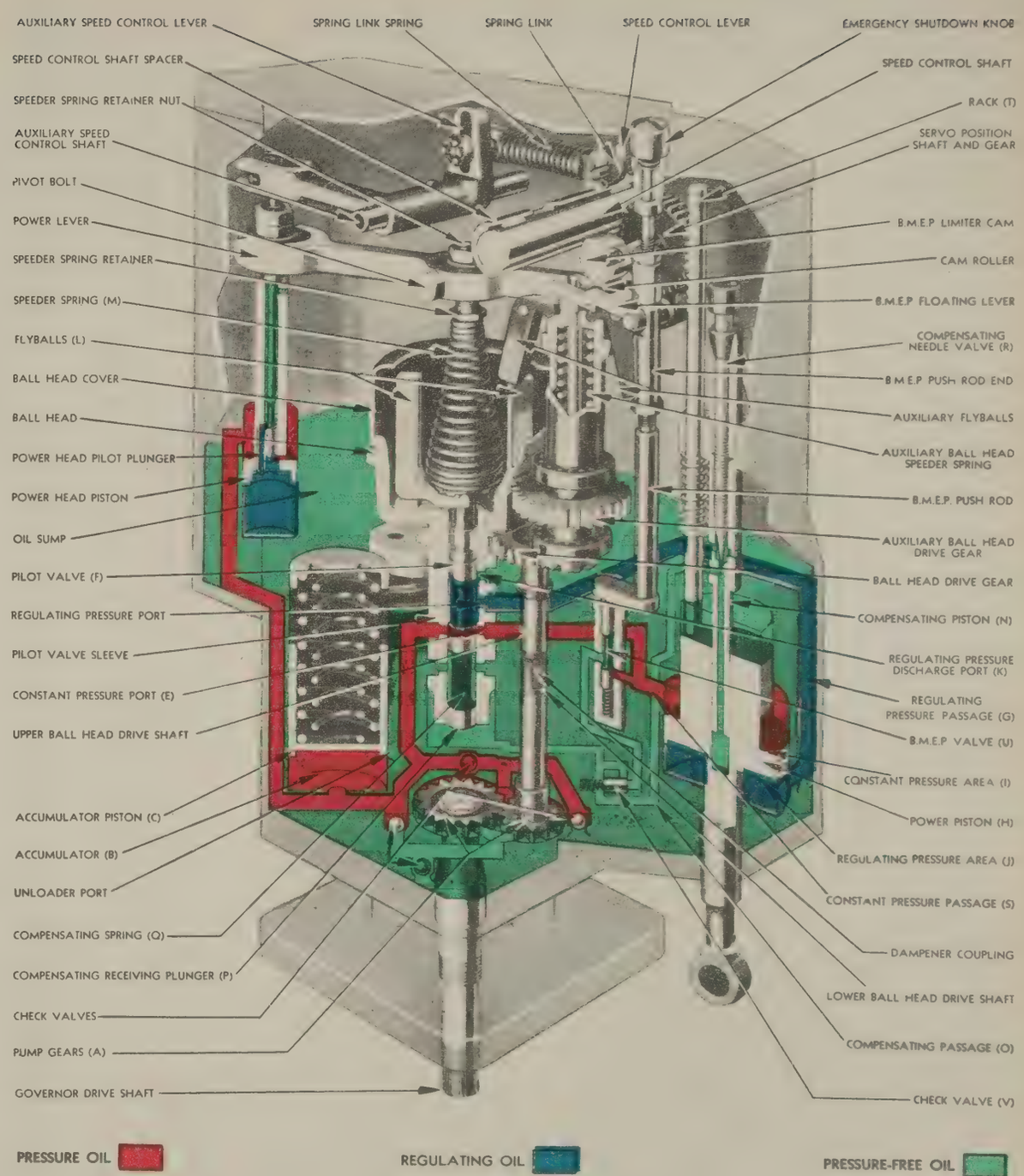

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Fig. 11M
Sheet 2

FUEL OIL SYSTEM

Description. The fuel oil pump draws fuel oil from the supply tank and forces it through a strainer-filter assembly. From the strainer-filter unit the fuel oil flows to the fuel supply manifold, which is the bottom pipe of the multiple pipe assembly on each cylinder bank, through a tube to a small filter on the cylinder head to the jumper tube that supplies the injector. The injector inlet contains a filter to further prevent solid matter from reaching the spray valve.

A safety valve on the outlet side of the pump limits the fuel oil in the system to a maximum pressure of 60 to 65 pounds per square inch, and excess oil is by-passed to the inlet side of the pump. A connection is placed ahead of the strainer-filter unit for use with a standby fuel oil pump.

The surplus fuel is by-passed in the injector and flows through another filter in the outlet passage so that any reverse flow of fuel cannot carry dirt into the injector. The surplus fuel passes from the injector through the jumper tube to the bleed manifold, which is the middle pipe in the multiple assembly on each cylinder bank. The fuel from the two bleed manifolds flows through a spring-loaded relief valve, which is adjusted to set up enough resistance to maintain the correct pressure (see Section C) in the fuel supply manifolds, and then flows back to the supply tank. (See Fig. 1N.)

The Unit Injector

Description. On this engine, the fuel pump and spray valve are combined into a single and compact unit called a unit injector, which meters the fuel and also atomizes and sprays it into the cylinder.

As shown in Fig. 1J, the unit injector is held in position in a water cooled jacket in the center of the cylinder head. At the lower end, the injector forms a gas tight seal with the tapered seat in the cylinder head. All the injectors in this engine are alike and interchangeable. Fuel is supplied through jumper tubes with spherical type gasket-less connections.

The pumping function of the injector is accomplished by the reciprocating motion of the constant stroke injector plunger which is actuated by the injector cam on the engine camshaft, through the injector rocker lever.

The position of the plunger and thereby the timing is adjusted by means of the ball stud and locknut at the injector end of the rocker lever.

The quantity of fuel injected into each cylinder and, therefore, the power developed in that cylinder, is varied by rotating the plunger by means of the injector control rack. A rack adjustment (called the micro-adjustment) located on the control linkage permits balancing the load of each cylinder while the engine is running.

Operation. Referring to Fig. 4N, with the injector filled with fuel oil the complete cycle of operation is as follows:

As the plunger is moved downward by the rocker lever, fuel in the bushing chamber is first displaced through both ports into the supply chamber around the bushing, until the lower edge of the plunger closes the lower port. Fuel in the bushing chamber is then displaced through connecting central and transverse holes in the lower end of the plunger, and through the upper port into the supply chamber. Further downward movement of the plunger causes the upper lip to cover the upper port, and the fuel in the bushing chamber is then forced down through the spray valve.

Injection continues until the lower lip on the plunger uncovers the lower port in the bushing, and then the fuel by-passes upward through the holes in the plunger and through the lower port into the supply chamber. This lowers the pressure of the fuel remaining in the bushing chamber until the valve spring closes the valve and stops injection. On the return stroke, the upward movement of the plunger fills the bushing chamber with fuel oil which flows from the supply chamber, through the ports.

The cylinder load (amount of fuel sprayed into the cylinder) is controlled by the rotation of the plunger as shown in Fig. 3N. Rotating the plunger locates the helical plunger lips with respect to the port openings in the plunger bushing and thereby controls the amount of fuel injected into the cylinder.

Engine performance usually indicates a defective injector when:

1. The exhaust temperature of any one cylinder drops more than 100° F. from normal.

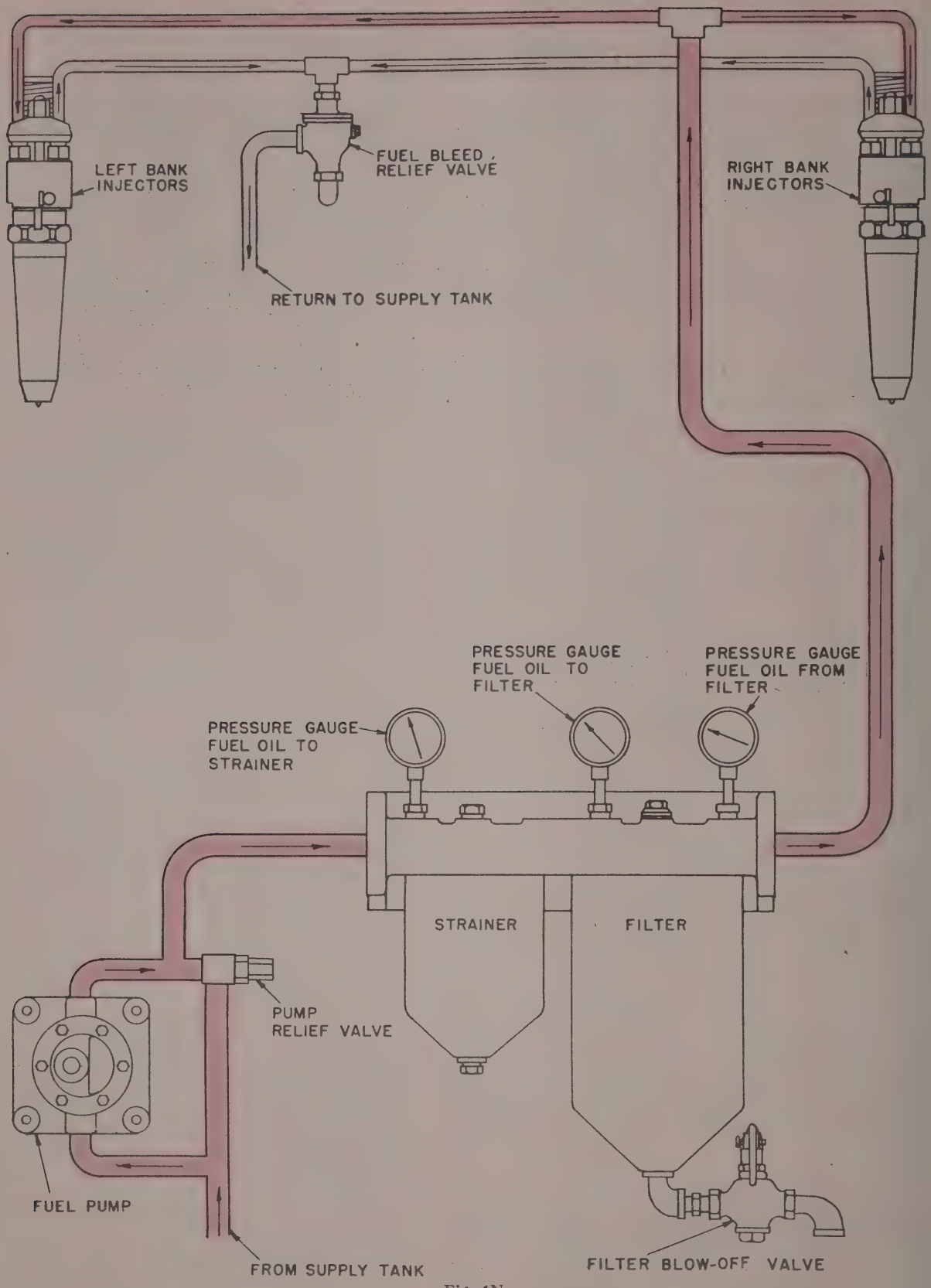


Fig. 1N
Fuel Oil System

2. The engine continues to fire on one cylinder when throttle is in STOP position.
3. Excessive fuel oil is found in the engine cylinder when starting.

Removing the Injector.

1. Remove cylinder head cover.
2. Remove rocker shaft lubricating oil line.
3. Remove cylinder head cover bracket.
4. Remove clevis pin from overspeed lock lever.
5. Remove rocker levers and bearing caps as an assembly.
6. Remove fuel oil jumper tubes.
7. Remove injector hold-down nut and clamp.
8. Remove injector. If injector sticks in cylinder head, the end of a suitable pinch bar may be inserted under one side of the injector body to pry injector loose. After removing injector, plug injector hole to keep dirt out of cylinder.

Before removing any cylinder head the injector should always be taken out to prevent injury to the spray tip which projects below the lower surface of the head.

Testing the Injector. Whenever an injector is removed from the engine it should be tested before it is re-installed.

A fixture, shown in Fig. 2N, is furnished for use in disassembling, assembling, and testing the fuel injector. Unless the tests indicate that the injector is faulty, or the spray tip holes are clogged, it should not be disassembled.

Great care must be taken to avoid injury to the hands and fingers when testing injectors. The high-pressure oil spray of an injector has sufficient penetrating power to puncture the flesh of the fingers or hand and destroy the tissues. The oil entering the blood stream may cause blood poisoning.

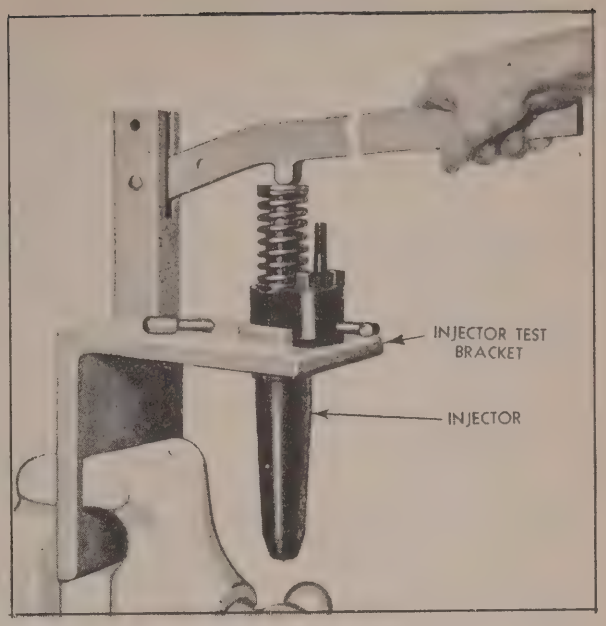


Fig. 2N
Testing Injector in Test Bracket

The procedure for testing the injectors is as follows:

1. Mount injector in socket plate of test fixture. (See Fig. 2N.)
2. Fill with clean fuel oil.
3. With rack withdrawn from injector as far as possible, slowly depress plunger with hand lever and *observe*:
   a. No fuel should be forced from spray orifices.
   b. Plunger should feel free in bushing.

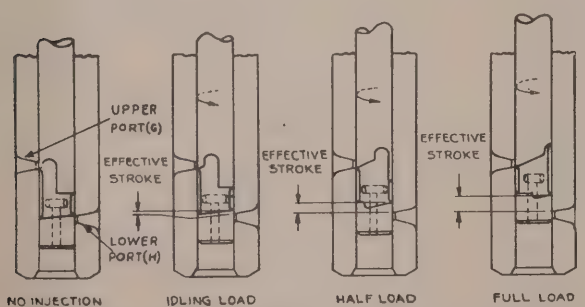


Fig. 3N
Load Control from "Full Load" to "No Load" Produced by Rotating Plunger with Control Rack

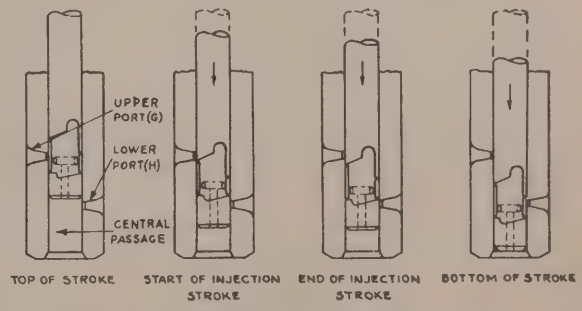


Fig. 4N
Phases of Injector Operation by Vertical Travel of Plunger

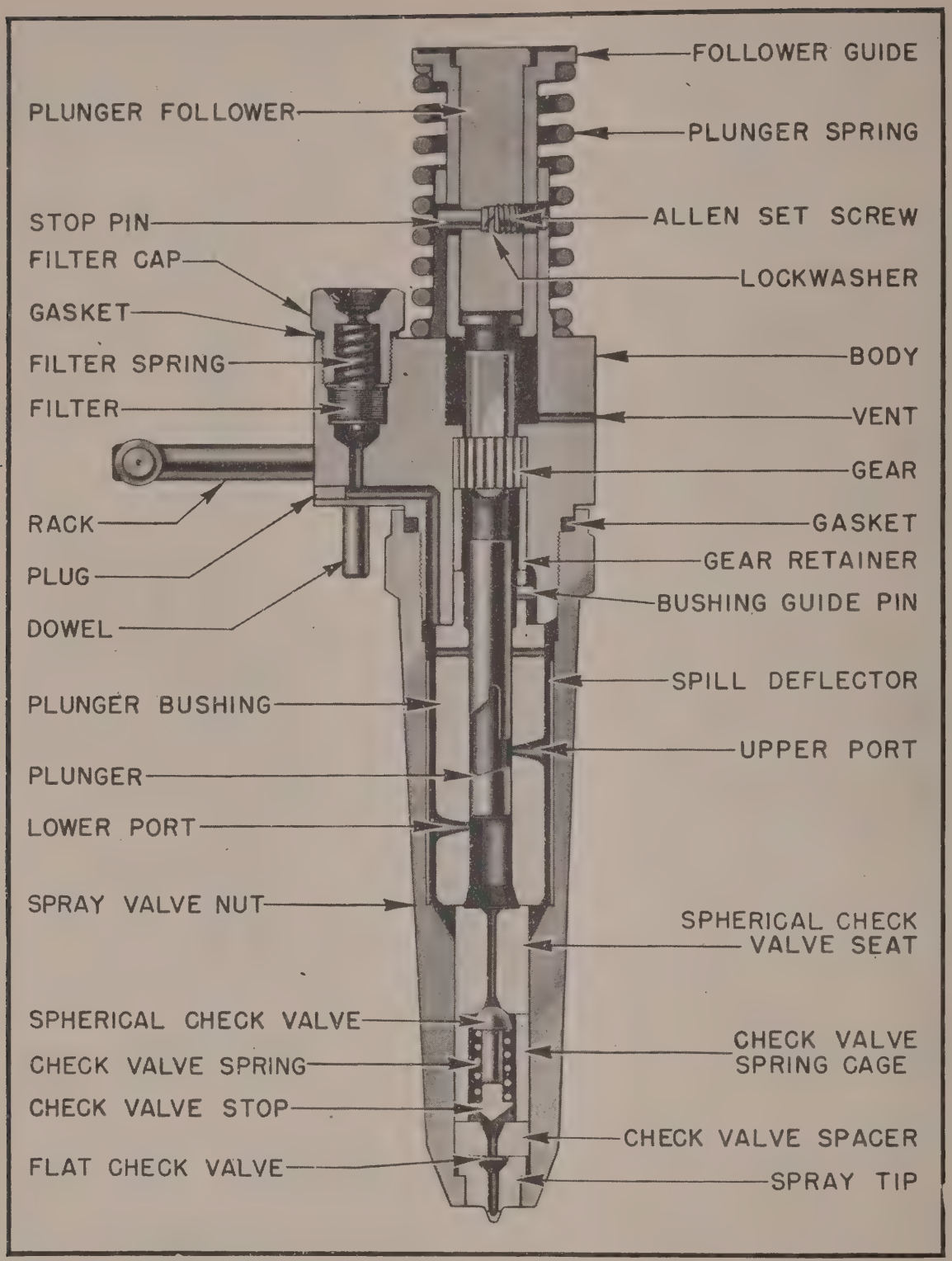


Fig. 5N
Cross Section of Injector with Spherical Check Valve

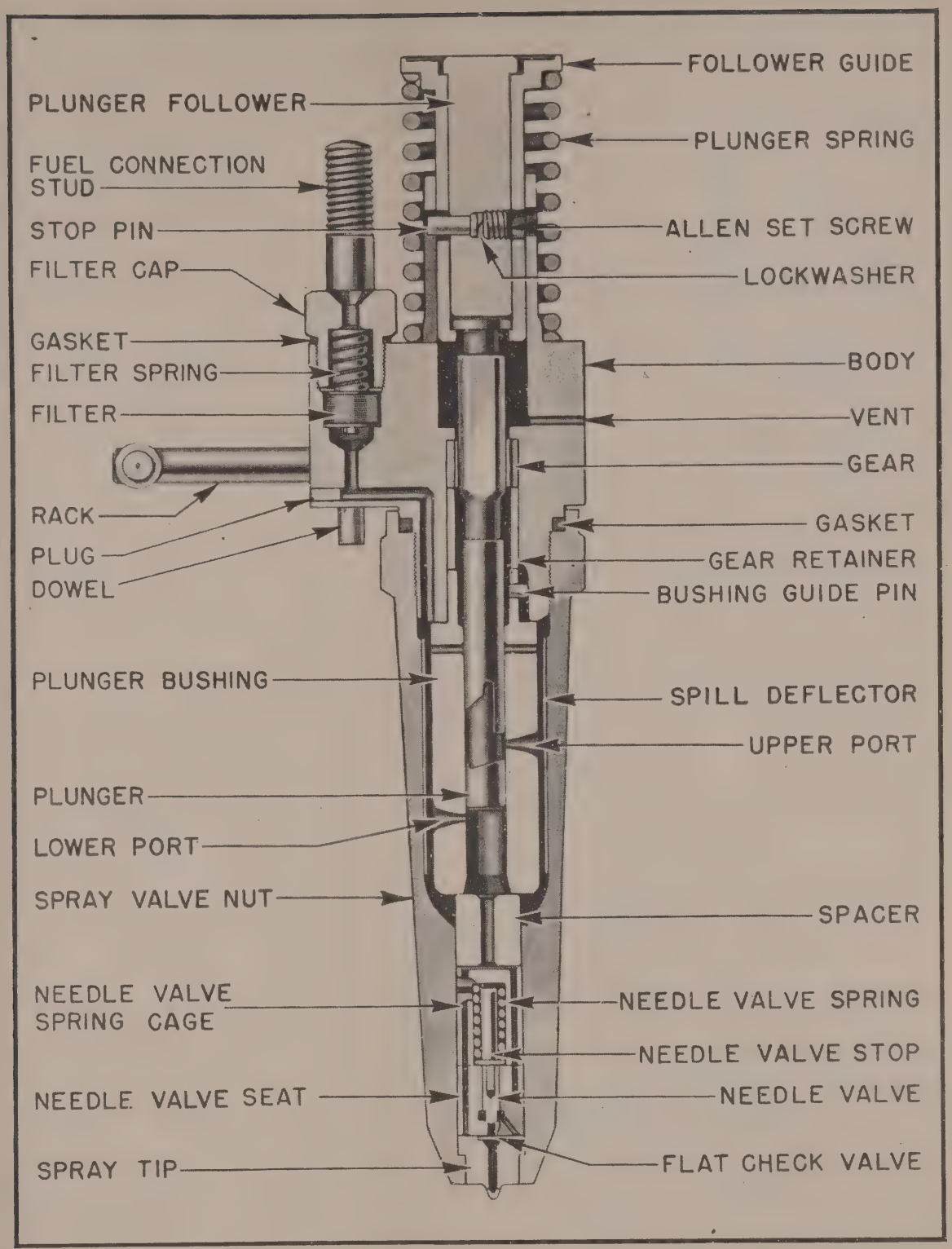


Fig. 6N
Cross Section of Injector with Needle Valve

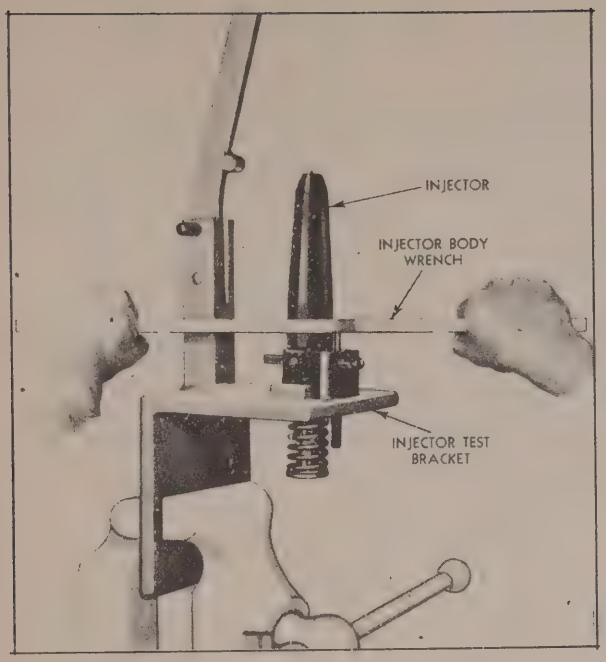


Fig. 7N
Removing Injector Spray Valve Nut

4. Now move rack in to limit of travel. Move rack slowly in and out while allowing plunger to return to top of stroke. Rack must be free for all positions.
5. Operate the plunger through its full stroke at a rate of 60 strokes per minute, and slowly move rack in. Fuel should start coming out of spray orifices when rack is approximately 3/16" from outer end of rack travel.
6. With rack in full "On" position, operate plunger at rate of 60 or more strokes per minute and observe whether fuel is being forced equally from all spray orifices. Fuel should be atomized when plunger speed is high enough. Depressing plunger slowly may give appearance of oil dribbling from spray tip.

Dismantling. In case it should be necessary to dismantle the injector proceed as follows:

Note: Before starting to disassemble an injector it is necessary to have a clean bench on which to work and store the parts. If more than one injector is disassembled, it is good practice to keep the parts of each injector separate.

1. Place injector upside down in test fixture.
2. Loosen spray valve nut with special wrench and unscrew by hand, Fig. 7N. Lift spray valve nut straight up taking care not to disturb the spray valve tip parts.
3. Remove the spray valve tip parts. Keep the parts of the valve assembly together as a unit, because it insures that the pressure required to open the valve will be the same as it was before dismantling. In injectors with needle valves, the valve guide and valve needle must be kept together as a unit.
4. In injectors of the needle valve type, a stuck valve needle should be removed from the valve guide by hydraulic pressure. For this purpose the spray valve is assembled without the spring, stop pin, and the check valve disc. A piece of brass shim stock is inserted between the spray tip and the valve guide. This sealed spray valve assembly is replaced in the injector. One stroke of the hand lever dislodges the stuck valve needle.
5. Remove the bushing and spill deflector or nut liner, and spacer, gear, and rack.
6. Screw empty spray valve nut on the body to protect the threads and plunger. Place the injector into the test fixture right side up.
7. Remove filter caps with box or socket wrench and remove filter spring and filter.
8. Compress the plunger spring slightly with hand lever and back out Allen setscrew enough to allow the stop pin to clear the slot in the body. Carefully unload the plunger spring and remove follower guide, plunger spring, plunger follower and plunger. The plunger must always be fitted with the same bushing. They are identified by a serial number etched on the two parts.
9. Remove the injector spray valve nut.

After the injector has been completely disassembled the parts should be thoroughly cleaned with a brush in carbon tetrachloride or similar cleaner, and dried with high pressure filtered air.

Injector Body Inspection. The interior parts of the body, including all passages and threaded portions, should be carefully inspected. There should be no slivers or broken threads that may become loose when the threaded parts are screwed into place, and that may lodge in the oil passages in the body.

Filter Inspection. (Stacked disc type.) The filtering elements should be inspected to see that

none of the spacers or discs are injured on their edges. Anything that tends to hold the element discs and spacers apart will permit dirt particles to pass through the filter.

Filter Inspection. (Sintered bronze type.) Whenever the injector is dismantled, new filters should be installed. Be sure no burrs or dirt will prevent filter from seating properly.

Control Gear and Rack Inspection. These parts should be free from burrs and rough spots so that the rack will move freely when the injector is assembled. There should be no appreciable backlash between the rack and the gear.

Plunger and Bushing Inspection. The working clearance between the plunger and bushing is very small, but the plunger should move freely in the bushing when lubricated with clean oil. If the plunger sticks at any position in the bushing, the parts should be thoroughly cleaned, lubricated with clean oil, and the fit checked again. If the tightness is still evident, and the surfaces are not scored, then the plunger is bent and both the plunger and bushing should be renewed.

Scored surfaces are easily seen on the plunger but the bushing should be inspected with a good light shining into the bore. Scoring from dirt is generally found around the port holes of the bushing. No attempt should be made to use a scored bushing even if the plunger has a free fit. Emery cloth, or grinding or lapping compound, should never be used on the bushing or plunger. If either part is scored, both the plunger and bushing must be renewed.

The plunger should also be inspected for chipped or broken edges, especially on the upper and lower helical lips because this changes the metering of the fuel. A broken edge may score the bushing. A plunger with chipped edges should be renewed together with its mating bushing. When the injector is dismantled, it is good practice to keep the plunger in the bushing as a protection for the lapped surfaces.

Spray Valve Assembly. Either of two types of spray valve assemblies are furnished. The spray valve assembly includes several lapped, oil tight joints that are subjected to the full injection pressure. These lapped surfaces should be carefully inspected for slightly burred edges, oil stains, scratches, or cracks. The imperfect sealing surfaces should not be lapped together but lapped separately on a grooved, cast iron flat lapping plate, provided as a special tool. (See Fig. 8N.)

A slightly burred edge, which is difficult to see, may be detected by a slight drag when sliding the sealing surface over an entirely clean part of the lapping plate. It is desirable to apply this test to all sealing surfaces that appear to be faultless under visual inspection, and to maintain a part of the lapping plate in a thoroughly clean condition for this purpose. An oil stained surface should be cleaned and polished on the lapping plate. A sealing surface with a short scratch, but with a continuous sealing band on some part of the surface, needs only to be smoothed up on the lapping plate. A scratch that extends entirely across the sealing surface should be removed by lapping.

Silicon carbide, 600 grit lapping powder, must be used in the dry condition. The chief use of the lapping plate is for cleaning and polishing the spray valve sealing surfaces, and therefore, only a very small amount of powder is necessary. Excessive lapping should be avoided because the end sealing surface may be lapped out of square with the axis of the part.

The valve guide and the spring cage should also be examined for cracks on the end faces, and if cracks are found, the parts should be renewed.

Ordinarily, the valve spring requires no attention, but the outside of the coils should be examined for bright marks which indicate that the coils have rubbed against the wall of the spring cage.

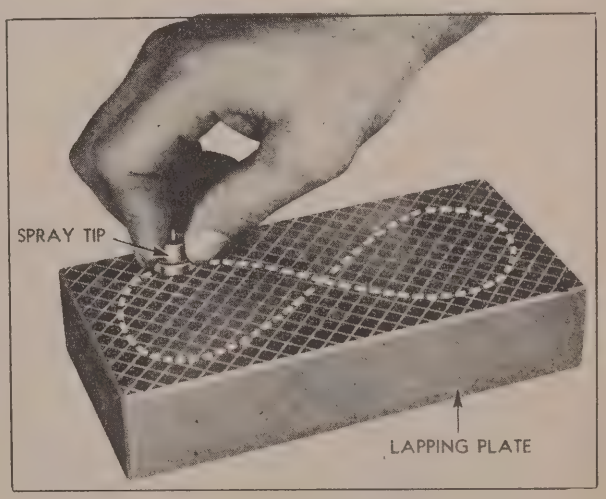


Fig. 8N
Lapping Spray Tip

The carbon deposits on the outside of the spray valve nut should be removed with a fine wire brush to avoid cutting deep scratches on the spherical seating surface. The inside surfaces of the nut, particularly the spray tip seat, should be examined and thoroughly cleaned to make sure that, when assembled, the seat joint will seal against the high-pressure combustion gases.

The carbon coating on the outside of the spray tip should be removed. The central hole in the spray tip should be examined and any carbon that may have collected in the bottom should be removed to prevent it from building up to the level of the spray orifices. If several of the spray orifices become blocked from the inside, the plunger pump may build up sufficient pressure to split the spring cage or fracture the end of the spray tip. This cleaning of the central hole is done with a drill which has been ground to fit. (Refer to Fig. 9N.) The flat surface of the tip should be cleaned and polished on the lapping plate.

Each of the spray holes in the tip should be cleaned, see Fig. 10N, and the size of the openings should be checked with music wire having the same diameter as the spray holes.

The check valve seat in the spray tip may show carbon deposits which should be removed. The lapping plate may be used for cleaning the flat surfaces of the check valve disc. A valve disc that shows excessive wear should be renewed because the resulting increased valve lift will cause faulty check valve action.

Assembling Precautions. When preparing to assemble the injector, it is necessary to clean all of the parts by washing them in carbon tetrachloride or similar cleaner. It is essential to do the washing in a thoroughly clean container. The parts should be further cleaned with filtered high pressure air. Make sure that all of the passages in the injector body, and all of the drilled holes, ports, and slots in the parts are clean. Waste or rags should not be used for cleaning because lint or loose particles may be left in the injector parts. Toilet tissue paper can be used for drying the lapped surfaces. The injector should be assembled as soon as possible after cleaning.

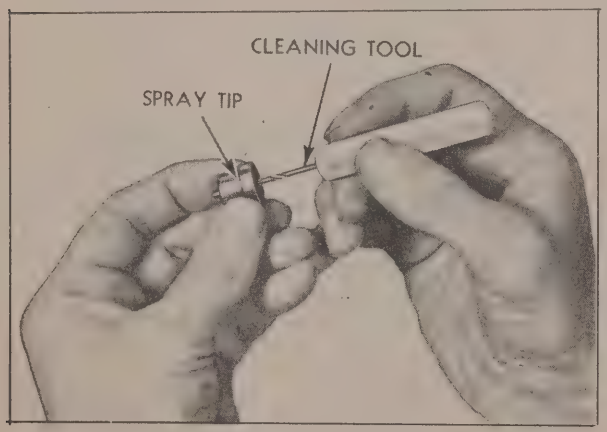


Fig. 9N
Cleaning Spray Tip

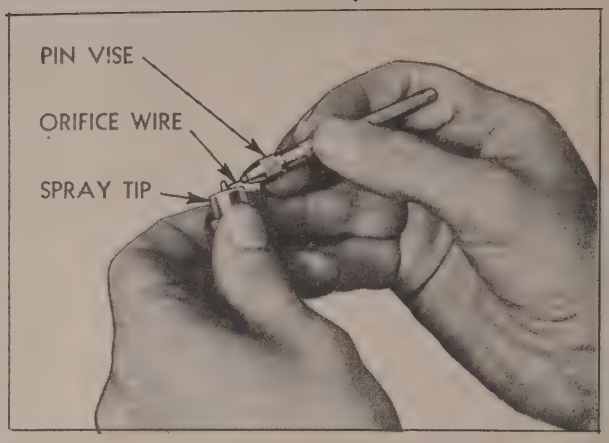


Fig. 10N
Cleaning Spray Tip Orifices

A preferred lubricant for general use in assembling an injector is a clean, rust-proofing oil of the medicinal mineral oil type. If this oil is not available, then a very light grade of acid-free lubricating oil or turbine oil may be used. If fuel oil remains on the closely-fitted surfaces of an inactive injector for a long period a gummy deposit may form and interfere with satisfactory injector operation.

Assembly Operation.

1. Screw a clean empty spray valve nut on the body to prevent injury to the threads when handling the injector.
2. Insert the two filter elements in the inlet and outlet filter cells in the body.
   a. *Stacked Disc Type Filters.* Be sure that the open end of the filter is placed toward the inside so that the coil spring bears on the closed end of the element.
   b. *Sintered Bronze Filters.* Be sure to insert the large end first.

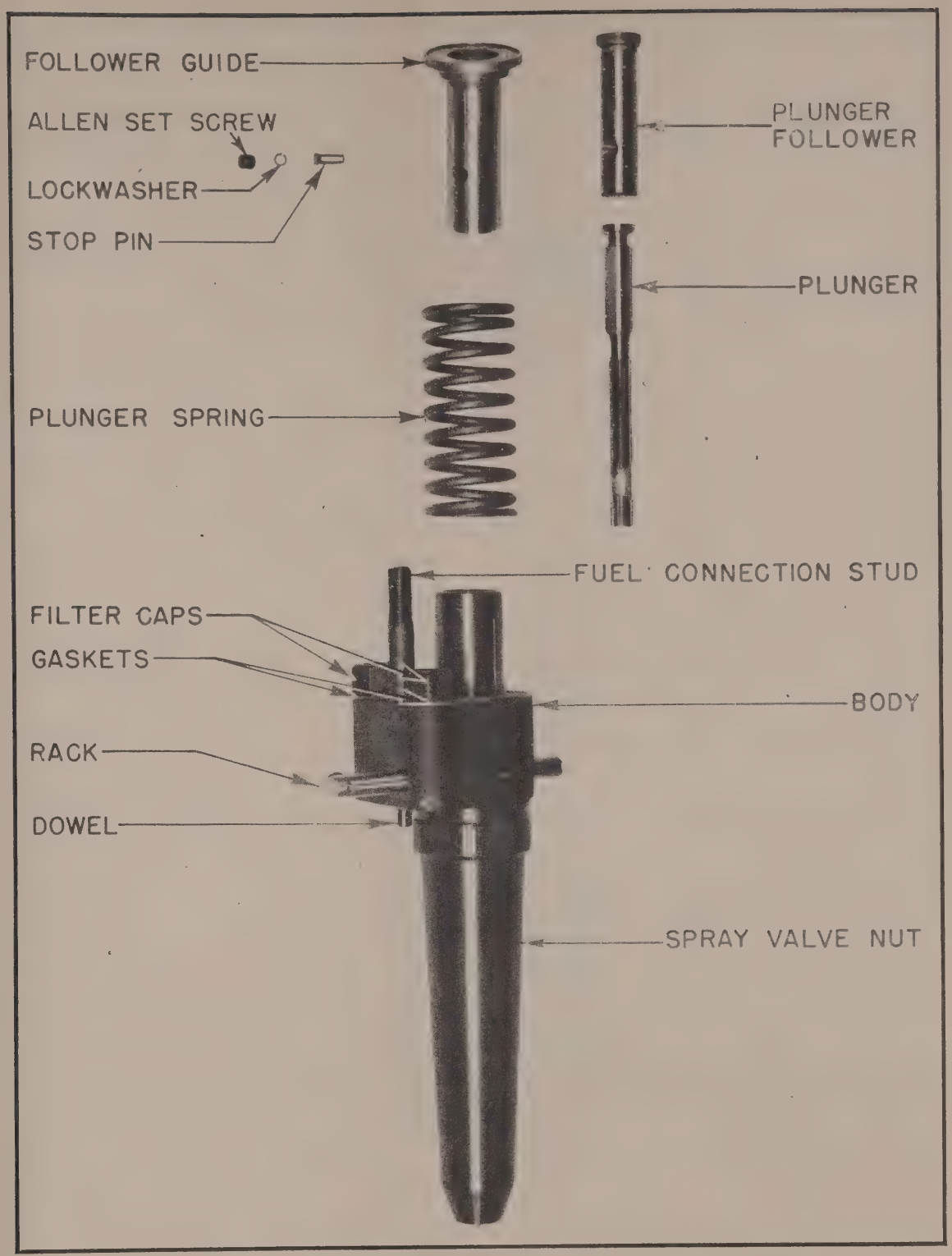


Fig. 11N
Relative Arrangement of Plunger Assembly Parts

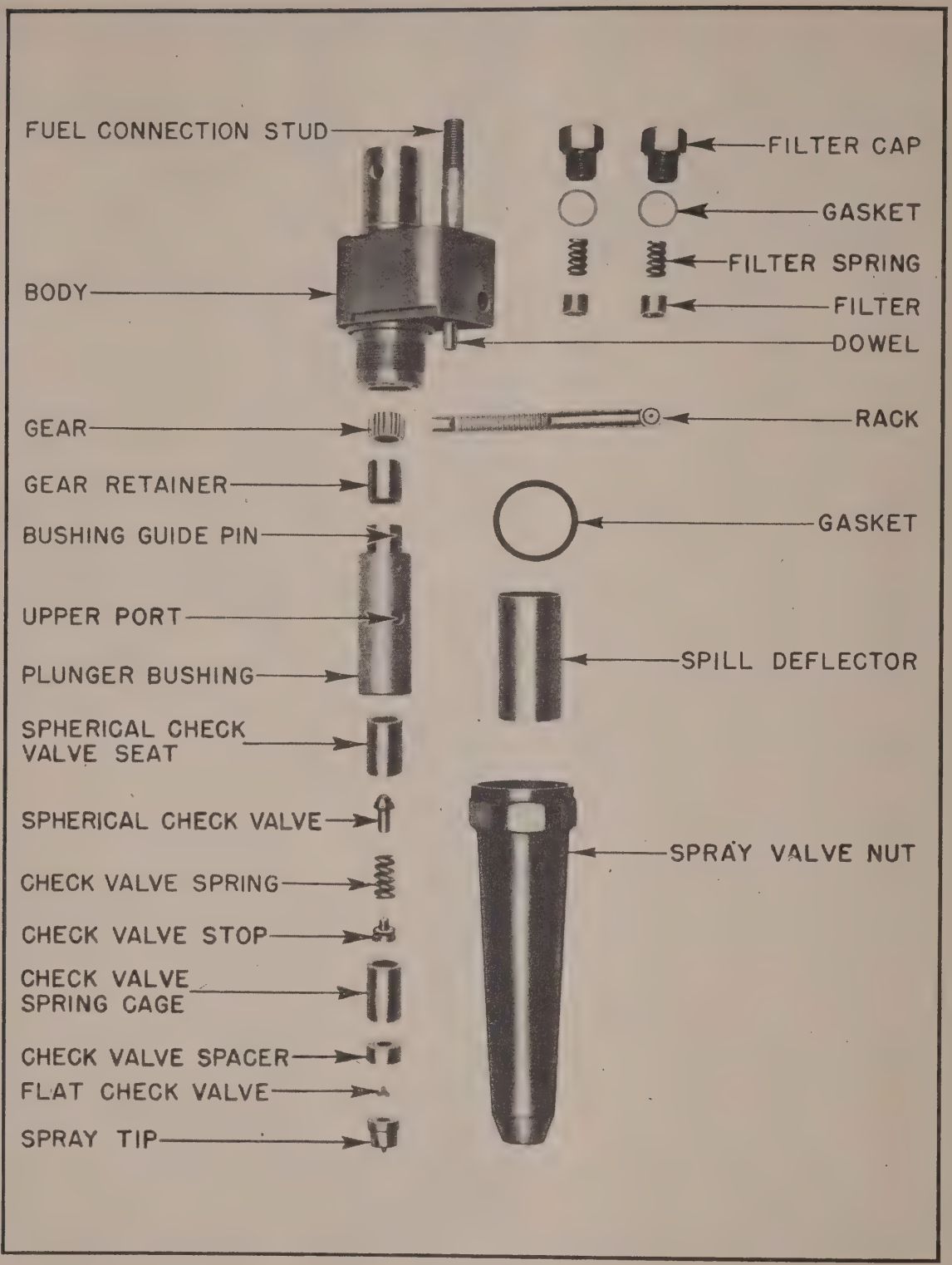


Fig. 12N
Relative Arrangement of Bushing and Spray Valve Assembly Parts for Injector with Spherical Check Valve

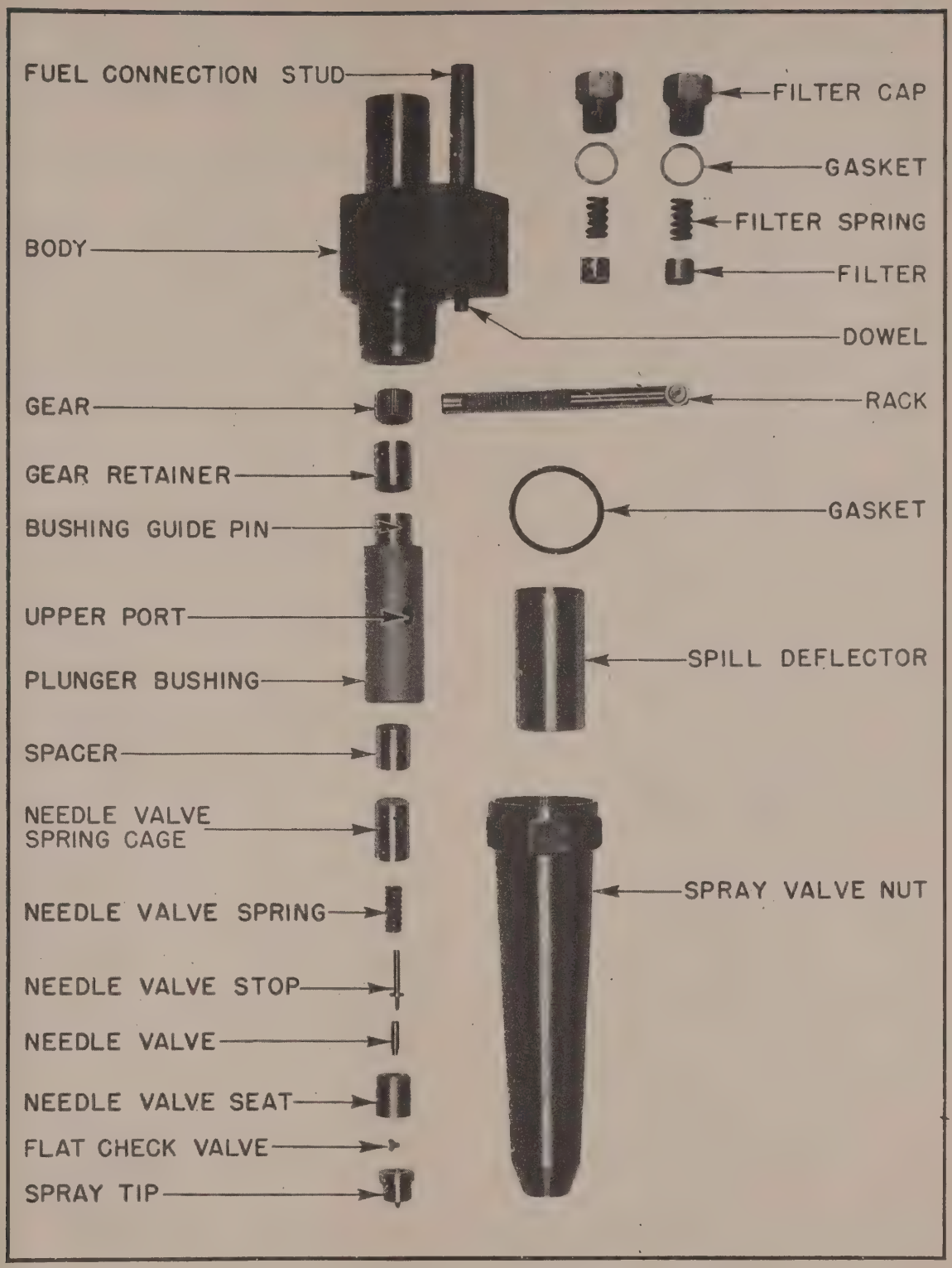


Fig. 13N
Relative Arrangement of Bushing and Spray Valve Assembly Parts for Injector with Needle Valve

3. Insert coil filter springs and filter caps using a new copper gasket under each cap.
4. Place the injector in the test fixture for final tightening of the filter caps.
5. Insert the plunger in the follower guide, place plunger follower in guide.
6. Place plunger spring over assembly and clean plunger with toilet tissue.
7. Lower the plunger into the body after aligning the follower guide slot with the retainer pin hole.
8. Line up holes in plunger follower and plunger follower guide with slot in injector body and insert stop pin lockwasher and setscrew between spring coils and tighten.
9. Remove injector from test fixture and turn upside down. Remove the spray valve nut being very careful not to strike the plunger and injure the metering lips.
10. Insert gear rack and drop gear over plunger so that punch mark on gear is centered between two punch marks on rack. This is the only assembly timing operation required. Insert gear retainer over the plunger on top of the gear.
11. Place the spill deflector or liner over the bushing. Clean the exposed end of the plunger with compressed air and lower the bushing over the plunger entering the dowel into the slot in the body. Place a new synthetic rubber gasket over the threaded end of the body.
12. Lubricate the threads of the body with a thin coat of air floated, powdered graphite made into a paste with engine lubricating oil. Coarser graphite would not pass through the spray valve if these particles accidentally entered the fuel passage.
13. Lubricate the lapped faces of the spray valve parts with clean lubricating oil to prevent scoring in the tightening operation, and place the parts in their correct order on top of the bushing.
14. Lower the spray valve nut carefully over the spray valve parts and screw into place by hand.
15. Tighten the nut with the special wrench until metal to metal resistance is felt and then tighten one quarter to one third turn more.
16. Test the injector as outlined.
17. If the injector is to be stored it should be filled with medicinal mineral oil or some suitable rust proofing compound.

Installation of the Injector in the Engine

Although the installation of the injector in the engine is very simple, there are several points in the procedure that should be emphasized.

Fuel Jumper Tubes. Before connecting fuel jumper tubes to the injector, the tubes and connections should be thoroughly cleaned with high pressure air. Many failures in the operation of the injector have been traced to dirt in the connecting lines.

Before installing each fuel jumper tube assembly on the engine, it should be checked to be sure the tube seats are clean and in good condition. Any dirt or mars on the seats will cause the connections to leak, which will result in fuel dilution of the lubricating oil.

Replacing the Injector. When the injector has been removed from the cylinder head and is to be replaced by another one, the adjusting screw in the rocker lever should be backed off to the upper end of its adjustment before the replacement injector is installed. When the replacement injector has been installed in the head, the plunger stroke must be retimed. This should be done, because two injectors may not seat at exactly the same height in the tapered hole in the lower deck plate of the cylinder head; and if it were not done, there would be no assurance that the replacement injector is correctly timed.

Installing the Injector.

1. Remove plug from injector hole. Make certain new synthetic rubber seal is on injector body. Install injector. Be sure injector rack enters micrometer adjustment assembly. Replace injector hold-down crab and nut and tighten securely.
2. Replace fuel oil jumper tubes. Tighten nuts carefully to avoid damage to tube seats.
3. Install valve bridges.
4. Replace rocker arm assembly, including bearing caps, and cylinder head cover bracket. If a different injector is installed back out the rocker lever adjusting screw. Replace and tighten four bearing hold-down nuts and place cotter pin

in each. Use care to see that dowel enters rocker lever shaft.

5. Replace rocker shaft lubricating oil line.
6. Replace clevis pin in overspeed trip lock lever.
7. Adjust the valve clearance and time the injector as outlined under "Engine Adjustments" in Section E.

Fuel Oil Relief Valve

Description. (See Fig. 14N.) The fuel oil relief valve is a spring loaded pressure relief valve set to open at the correct pressure. (See Section C.) It is adjustable, and its design provides for a minimum of pressure blow-down. Fuel enters the valve from the fuel bleed line and is discharged to the fuel oil tank.

Maintenance. Only maintenance required is to see that the valve seat is kept clean and that the valve is properly adjusted. The pressure at which the valve operates is adjusted by removing the cap, turning the adjusting screw in to increase the pressure and out to decrease the pressure. Blow-down is adjusted by removing the locking plug from the bonnet and, with a small screwdriver, screwing the regulating ring up on the body to decrease blow-down and down to increase blow-down.

Remove Fuel Oil Relief Valve.

1. Disconnect fuel oil line to supply tank.
2. Remove relief valve clamp.
3. Unscrew valve from Tee connection.

Disassemble Fuel Oil Relief Valve.

1. Remove cap nut.
2. Remove adjusting screw and locknut.
3. Remove locking plug from side of bonnet.
4. Remove bonnet from body and remove spring washers, stem and disc.
5. Remove regulating ring.

Assembly of Fuel Oil Relief Valve.

1. Reverse of disassembly.

Install Fuel Oil Relief Valve.

1. Reverse procedure for removal.

Fuel Oil Pump

Description. The fuel oil pump is located on the blower end of the engine and is driven directly by one of the camshafts. It is of the positive displacement type. Fuel oil enters at the top and is discharged at the bottom of the pump casing. The rotor hub is pinned to the drive shaft and turns at engine speed. The idler is smaller in diameter and meshes with the rotor from the inside, its center being offset from the center of the rotor. The idler rotates on a shaft pressed in the head of the pump and is driven by the rotor. A spring loaded packing prevents fuel oil from leaking around the shaft of the pump.

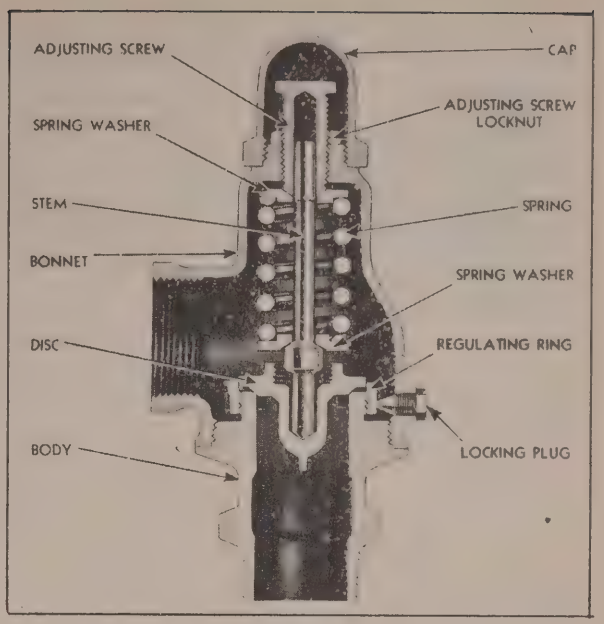


Fig. 14N
Fuel Oil Relief Valve

Maintenance. If fuel oil leaks excessively around the shaft the packing must be renewed, as the packing cannot be adjusted manually. Remove the pump from the engine and remove the packing nut, gland and packing. Renew packing on gland ring and install gland and packing nut. Pull up tight.

If it becomes necessary to renew the bushings, the casing bushing is easily removed from the casing with an arbor press. The idler bushing can be removed in the same manner.

Remove Fuel Oil Pump.

1. Disconnect fuel supply line and coupling to fuel oil filter-strainer unit.
2. Remove capscrews holding pump assembly to fuel pump bracket and remove pump.

Disassemble Fuel Oil Pump.

1. Remove Woodruff key from shaft.

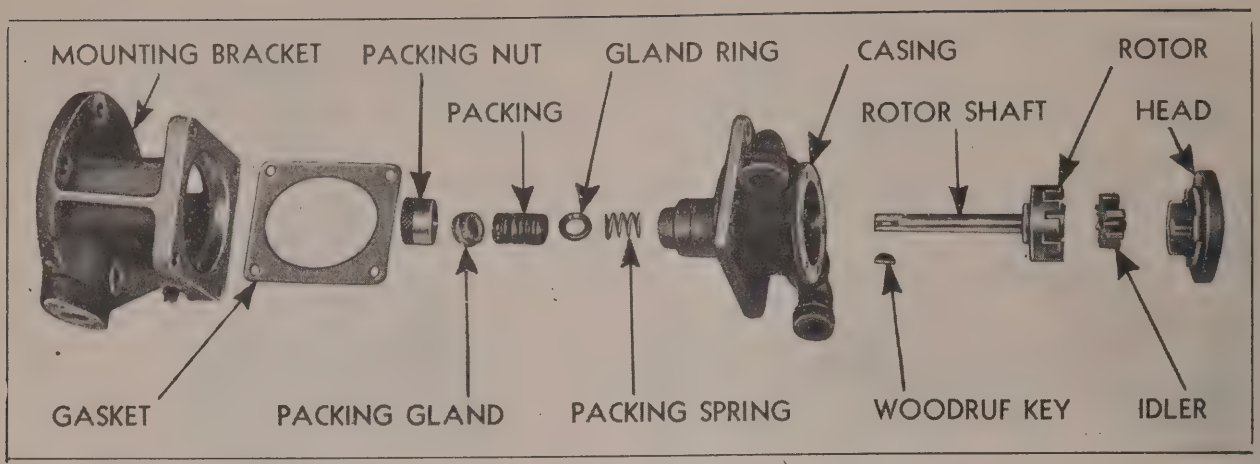


Fig. 15N
Fuel Oil Pump

2. Remove packing nut, gland, packing, gland ring, spring, and spring thrust washer.
3. Remove capscrews from head.
4. Remove head.
5. Lift out idler and bushing assembly.
6. Lift out rotor and shaft assembly.

Assemble Fuel Oil Pump. The assembly of the fuel oil pump is the reverse of the disassembly. Be sure that all bearing surfaces are clean and have the proper clearances. If the gasket between the casing and head has been damaged replace with new gasket.

Install Fuel Oil Pump.

1. Inspect and replace gasket between pump and bracket. Renew if damaged.
2. Balance of installation is reverse of removal procedure.

Cylinder Head Jet Filters

Description. The cylinder head jet filters are located in the fuel oil transfer block located on each cylinder head. (See Fig. 1J.) The element in each cylinder head is of the edgewise-wound metal ribbon type. This filter is correctly assembled when the helical spring and cap are placed over the projecting pin of the filtering element to hold the element flange against the shoulder at the inner end of the filter cell. (See Fig. 16N.)

Maintenance. A periodic inspection of one or more cylinder head filters will indicate when all of these filters require cleaning. The elements may be washed in carbon tetrachloride or similar cleaner and further cleaned with filtered high pressure air.

Remove Cylinder Head Filter.

1. Remove filter cap and gasket.
2. Remove filter element assembly.

Replace Cylinder Head Filter.

1. Insert filter element in body with the pin out.
2. Balance of assembly is reverse of disassembly.

Fuel Oil Strainer and Filter

Description. The fuel oil strainer and filter are mounted on a common head casting that is attached to a bracket fastened to the blower intake adapter housing. The fuel enters the head casting at the strainer end, passes from the outside of the strainer elements, to the center of each strainer element, up into a common head, through the head casting to the space around the filter element. After passing through the filter element, the fuel flows to the fuel supply manifold.

The fuel oil strainer is of the stacked disc type in which the metal strainer discs are stacked on rods and held together by a knurled nut on each rod. The strainer is composed of four elements. The element container is held to the head casting by a capscrew.

The fuel oil filter is of the renewable element type. That is, when the element becomes clogged with foreign matter it may be discarded and replaced with a new element. A blow-off valve at the bottom of the filter case should be opened periodical-

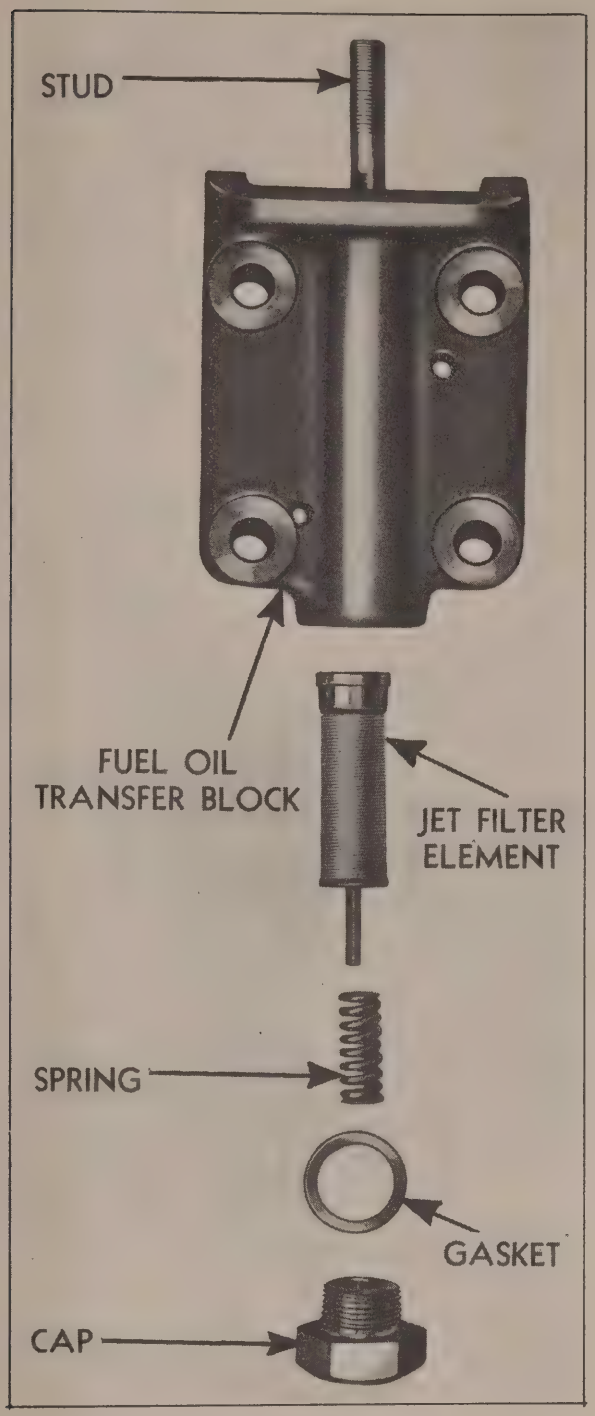


Fig. 16N
Fuel Oil Transfer Block and Filter

ly while the engine is running. This washes all the loose particles from the side of the element and permits the draining of any accumulated sludge or water from the shell.

Maintenance—Fuel Oil Strainer. Every few days, with the engine stopped, remove the plug in the bottom of the strainer unit and drain the sludge and water from the strainer casing. After every 500 hours of engine operation the strainer element should be removed and cleaned. After draining the element container the unit is removed by loosening the bolt which holds the casing to the head casting. Lift the element from the casing and clean by washing with a soft cloth and carbon tetrachloride or similar cleaner. Care must be taken to prevent dirt from getting between the discs when the element is being blown dry after being washed. The element must never be cleaned with a wire brush or scraper. Clean the casing and reassemble.

When reassembling, the gaskets should be inspected and renewed if damaged or broken.

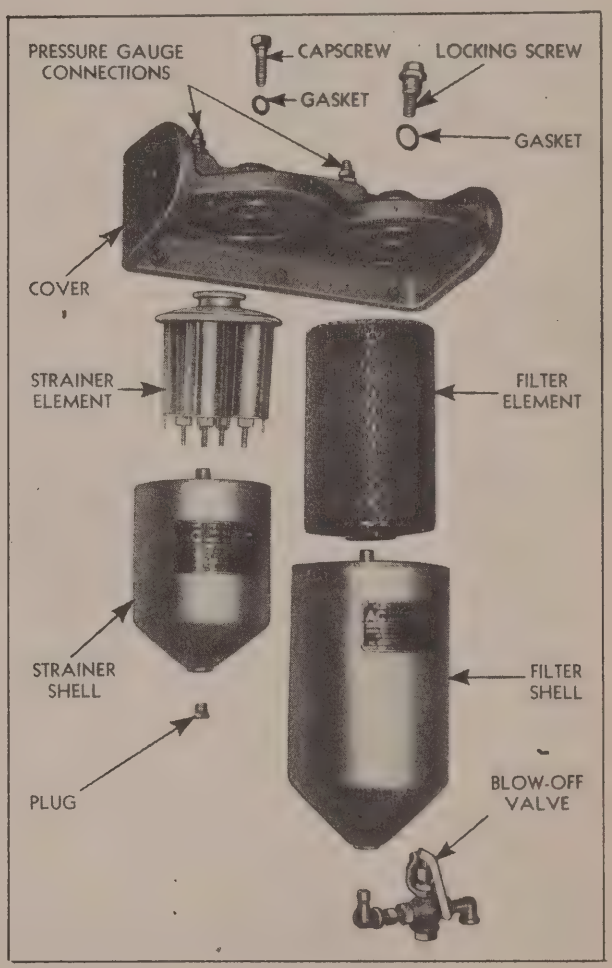


Fig. 17N
Fuel Oil Strainer-Filter

Maintenance—Fuel Oil Filter. The element in the fuel oil filter cannot be cleaned and must be renewed after every 500 hours of engine operation. Stop the engine before removing the filter element. Remove in the same way as the strainer element. The filter shell should be cleaned before a new cartridge is installed. The gaskets should be inspected and renewed if they are damaged or broken.

LUBRICATING OIL SYSTEM

Description. The lubricating oil pressure pump draws oil from clarifier and forces it through the lubricating oil cooler. From the oil cooler the lubricating oil is delivered to the engine lubricating oil system of the engine. The lubricating oil scavenging pump draws the oil from the oil pan through a suction strainer and returns it to the lubricating oil clarifier.

The lubricating oil enters the engine from the cooler at a connection on the control side of the camshaft drive housing. A regulating and relief valve keeps the pressure of the lubricating oil entering the engine between 40 and 50 pounds per square inch at full load and full speed. The oil by-passed by the relief and regulating valves is returned to the camshaft drive housing where it drains to the oil pan.

From the engine inlet connection the oil flows to the main lubricating oil manifold bolted to the bottom of the main bearing supports, and flows up through a drilled passage in the supports to the main bearings. The crankpin bearings are lubricated with oil that is received from the adjacent main bearings through oil passages in the crankshaft. A drilled passage in the connecting rod conducts this oil to the piston pin bearing and to the piston cooling chamber formed by an integral diaphragm under the piston head. Pressure lubricating oil flows from the top of the connecting rod, through a sealing member, and into the cooling chamber. The sealing member is a spring-loaded shoe which rides on the cylinder top of the connecting rod. The heated oil overflows through two drain passages.

The lubricating oil for the camshaft drive gear train is supplied by branch lines from the main lubricating oil manifold which conduct oil to the manifold distributor blocks on each side of the camshaft drive housing.

From each of the distributor blocks a pipe supplies oil to each camshaft drive gear bearing. The drilled camshafts are supplied through passages in the camshaft gear hubs and the camshaft drive sleeves. The camshaft bearings receive lubricating oil through radial holes in the camshaft bearing surfaces. Oil for lubricating the rocker lever mechanism flows through a tube from the camshaft bearing cap at each engine cylinder. This oil also lubricates the valve assemblies. The excess oil flows from the end of the camshafts down the camshaft drain tubes to the engine oil pan.

A manifold, bolted to the blower end of the main lubricating oil manifold, supplies the lubricating oil for the blower gears and bearings, and the accessory drive gears and bearings. The manifold carries oil to the blower rear end plate, to the blower front end plate, and the accessory drive housing. Steel tubing cast into the ribs of the end plates and the housing carry the lubricating oil to the blower drive gear bearings and to the gear bearings in the accessory drive. Excess oil drains through the lower blower housing into the oil pan.

The lubricating oil temperature is regulated by the temperature of the fresh water flowing through the lubricating oil cooler which in turn is regulated by the amount of sea water flowing through the fresh water cooler.

Lubricating Oil Pressure Pump

Description. The lubricating oil pressure pump is mounted on the camshaft drive housing cover and is a positive displacement helical spur gear type pump. The pump body and body base are bronze castings. Bronze bushings for the gear shafts are pressed into the housing and cover. The gears and shafts are integral steel forgings with the drive gear shaft extended and splined to fit into the hub of the oil pump drive gear in the camshaft drive. A cover closes the outside of the body.

P

Maintenance. When the lubricating oil pressure, as read by the lubricating oil "IN" pressure gauge at the engine inlet connection, drops noticeably, the following inspections should be made:

1. Check pressure regulating and relief valve to see that it is not stuck open or out of adjustment. (See page P-10.)
2. Check lubricating oil for fuel dilution.
3. Make sure the cooler is not plugged.
4. Check gauge against other gauges in the system. The readings should be relative.

If the cause of the low lubricating oil pressure is not found in the above inspections, the pump should be dismantled and the gears and bearings inspected

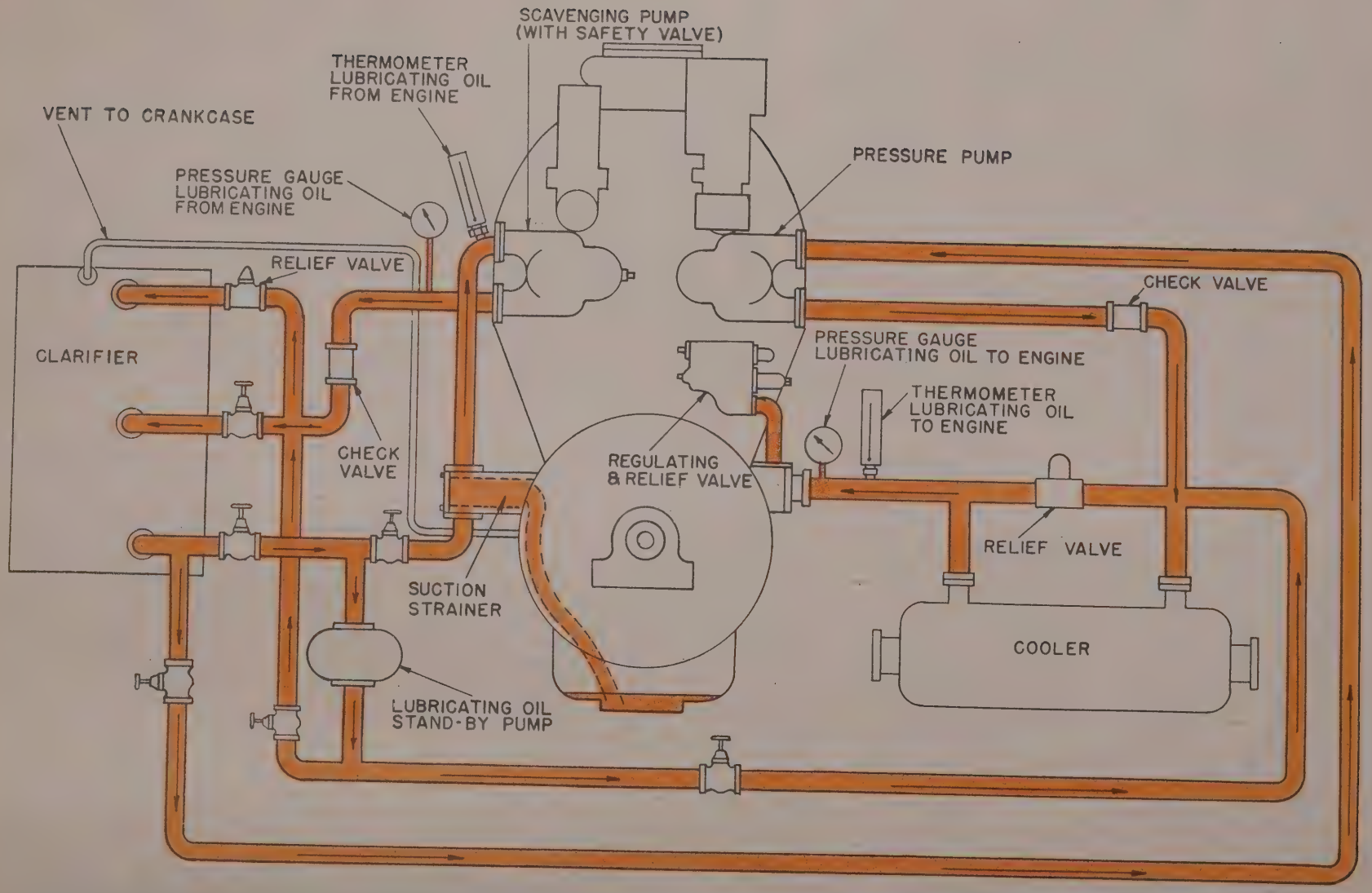


Fig. 1P
Lubricating Oil System

for wear. If excessive clearances are found the gears or bearings or both should be renewed.

Removing Lubricating Oil Pressure Pump.

1. Disconnect lubricating oil lines from pump flanges.
2. Remove hand control lever.
3. Remove capscrews and lockwashers from body flange.
4. Pry free from dowels and lift off.

Disassembly of Lubricating Oil Pressure Pump—Pump Removed from Engine.

1. Remove cover.
2. Remove body base.
3. Lift out gears.

Assembling Lubricating Oil Pressure Pump.

Reverse disassembly operations. Use new gaskets if any have been damaged.

Replacing Lubricating Oil Pressure Pump.

1. Inspect and install gasket between pump and camshaft drive housing.
2. Line up splines on pump shaft with drive gear hub and line up dowels.
3. Seat pump on camshaft drive housing with lead hammer.
4. Install lockwashers and capscrews and tighten.
5. Install hand control lever.
6. Connect lubricating oil lines.

Lubricating Oil Scavenging Pump

Description. The lubricating oil scavenging pump is the same type of pump as the pressure pump and is mounted on the camshaft drive housing cover opposite the pressure pump. A pressure safety relief valve is attached to the scavenging pump to prevent excessive oil pressures from entering the lubricating oil filter.

Maintenance. When the lubricating oil pressure as read by the lubricating oil "IN" pressure gauge at the filter drops noticeably, the following inspections should be made:

1. Check pump safety valve to see that it is not stuck open or out of adjustment. (See page P-9.)
2. Check lubricating oil for fuel dilution.
3. Make sure suction strainer is not plugged.
4. Check gauge against other gauges in system. The readings should be relative.

If the cause of the low lubricating oil pressure is not found in the above inspections, the pump should be dismantled and the gears and bearings

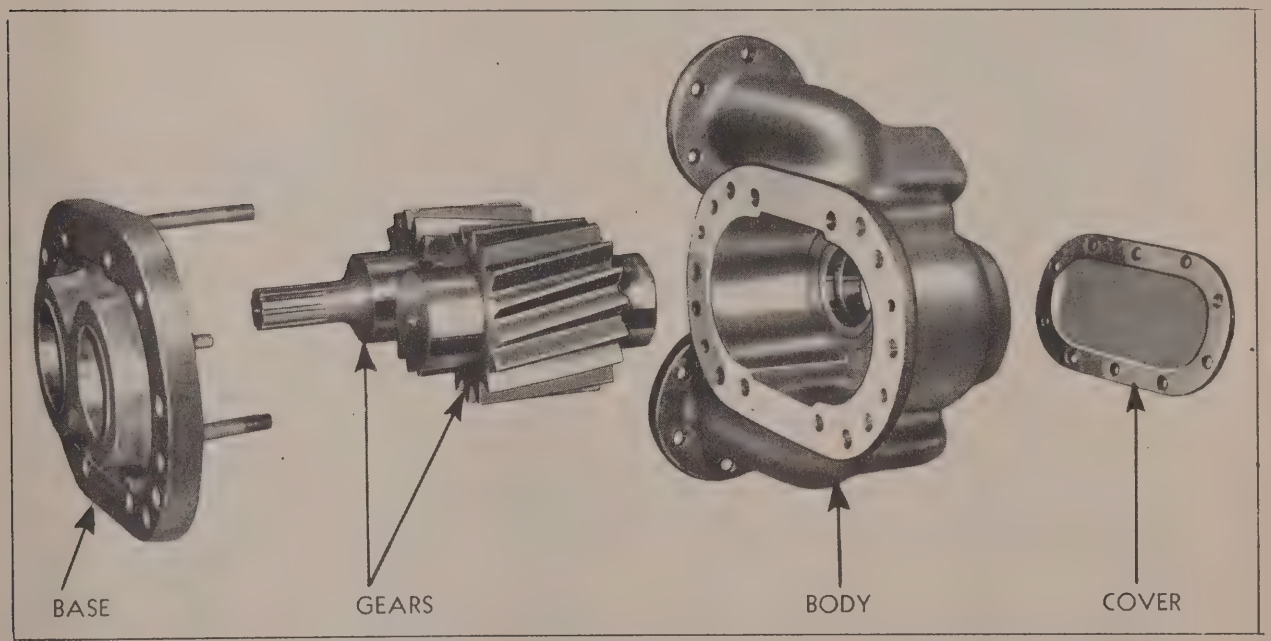


Fig. 2P
Lubricating Oil Pump

inspected for wear. If excessive clearances are found the gears or bearings or both should be renewed.

Removing Lubricating Oil Scavenging Pump.

1. Disconnect lubricating oil lines from pump flanges.
2. Remove pressure safety valve.
3. Remove capscrews and lockwashers from body flange.
4. Pry free from dowels and lift off.

Disassembly of Lubricating Oil Scavenging Pump—Pump Removed from Engine.

1. Remove cover.
2. Remove body base.
3. Lift out gears.

Assembling Lubricating Oil Scavenging Pump.

Reverse disassembly operations. Use new gaskets if any have been damaged.

Replacing Lubricating Oil Scavenging Pump.

1. Inspect and install gasket between pump and camshaft drive housing.
2. Line up splines on pump shaft with drive gear hub and line up dowels.
3. Seat pump on camshaft drive housing with lead hammer.
4. Install lockwashers and capscrews and tighten.
5. Install pressure safety valve.
6. Connect lubricating oil lines.

Suction Strainer

Description. The lubricating oil suction strainer is located in the scavenging pump intake line and is fastened to the camshaft drive housing. The straining element is a wire screen cylindrical in shape. The scavenging pump draws oil through the open end of the strainer element and out through the sides of the cylinder.

Maintenance. The element should be removed and cleaned when there is a drop in the lubricating oil pressure supplied by the pump or when the oil is changed.

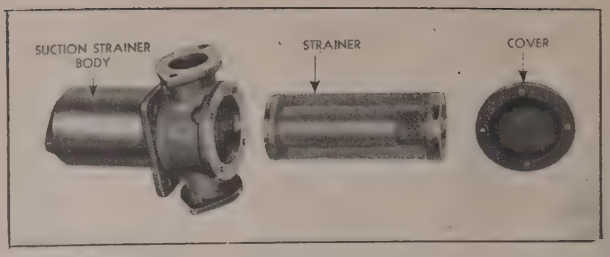


Fig. 3P
Suction Strainer

Remove Suction Strainer.

1. Remove capscrews holding strainer cap to housing and remove cap.
2. Remove strainer elements.

Install Suction Strainer.

1. Reverse removal procedure.

Lubricating Oil Filter

Description. The filter is a compact unit embodying the strainers, the refills, and the oil storage capacity within one rectangular, steel tank. The built-in relief valves are permanently set to maintain the correct pressure differential on the refills for proper oil clarification. Emergency relief valves are incorporated in the strainer compartment to relieve pressure in the event the strainers become plugged, and an auxiliary strainer is provided for by-passing oil into the storage compartment while refills are being changed.

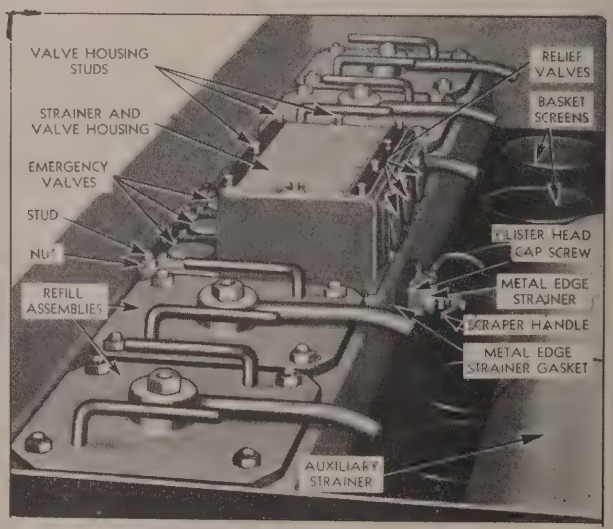


Fig. 4P
Top View of Filter—Cover Removed

Specifications.

Maximum recommended flow	85 g.p.m.
Oil required to fill filter	200 gals.
Storage compartment capacity	125 gals.
Minimum operating temperature	140° F.
Operating pressure differential	22 lbs.
Maximum working pressure	25 lbs.
Hydrostatic test pressure	37 lbs.
Clearance required to change refills	34 in.
Number of Briggs refills in filter	12
Number of strainers in filter	4
Strainer spacing	.005 in.
Dimensions:	
Length	72 in.
Width	24 in.
Height	50½ in.
Weights:	
Dry	1220 lbs.
Wet	2720 lbs.
Inlet and outlet connections	2½ in. I.P.

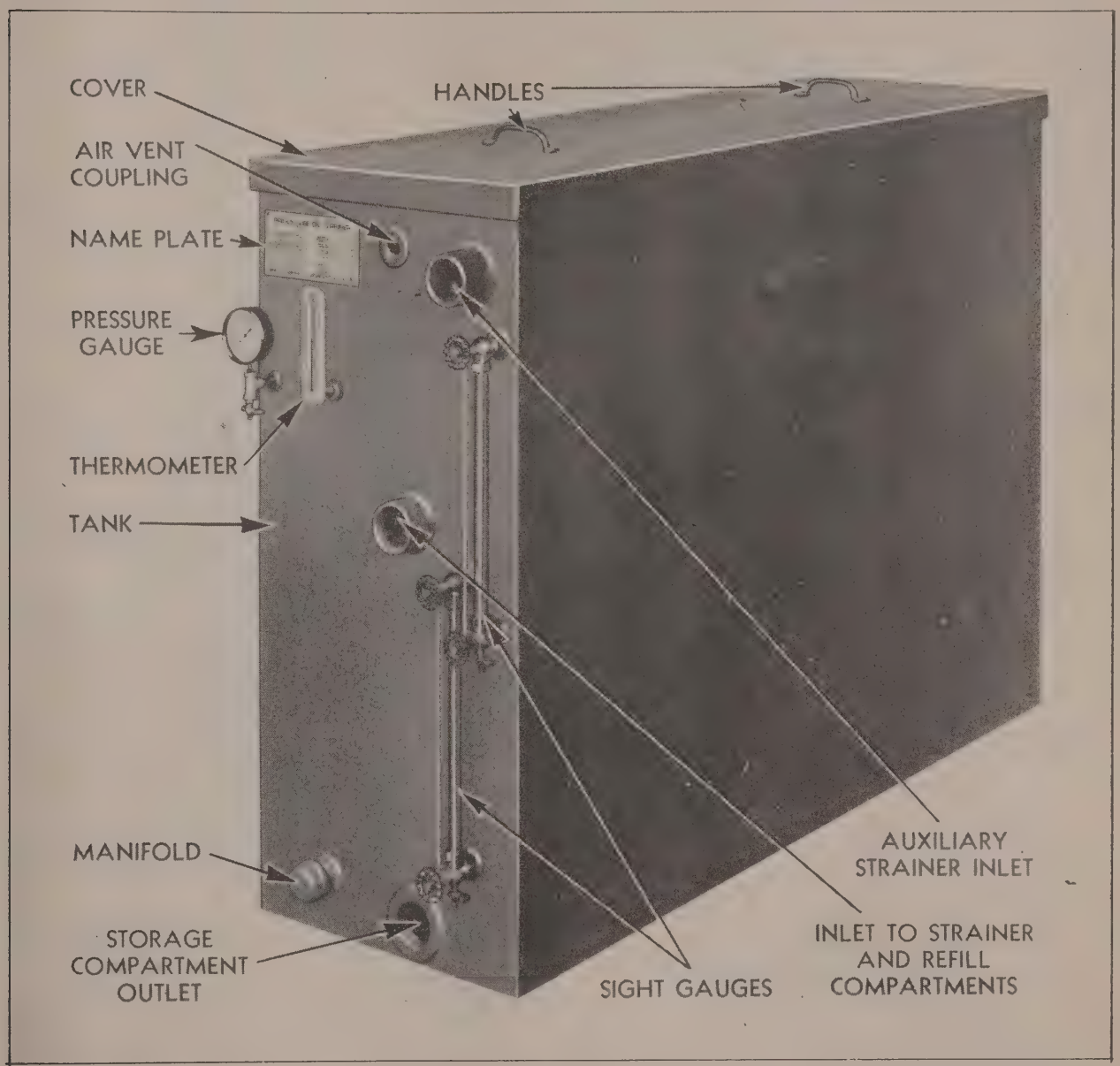


Fig. 5P
Lubricating Oil Filter

Maintenance. Before changing refills or cleaning strainers when engine is in operation, divert the oil flow through the auxiliary strainer. The strainers can be cleaned or the refills changed when the engine is shut down without taking this precaution. No oil should enter the strainer or refill compartments.

If Cellulose Refills (D-Cel) are used, unless otherwise instructed the refills should be changed when the oil shows a percipitation number of more than .04 by chemical analysis.

If Fuller's Earth Block Refills (B) are used, the refills should be changed when the oil begins to darken, or when, by chemical analysis, the oil

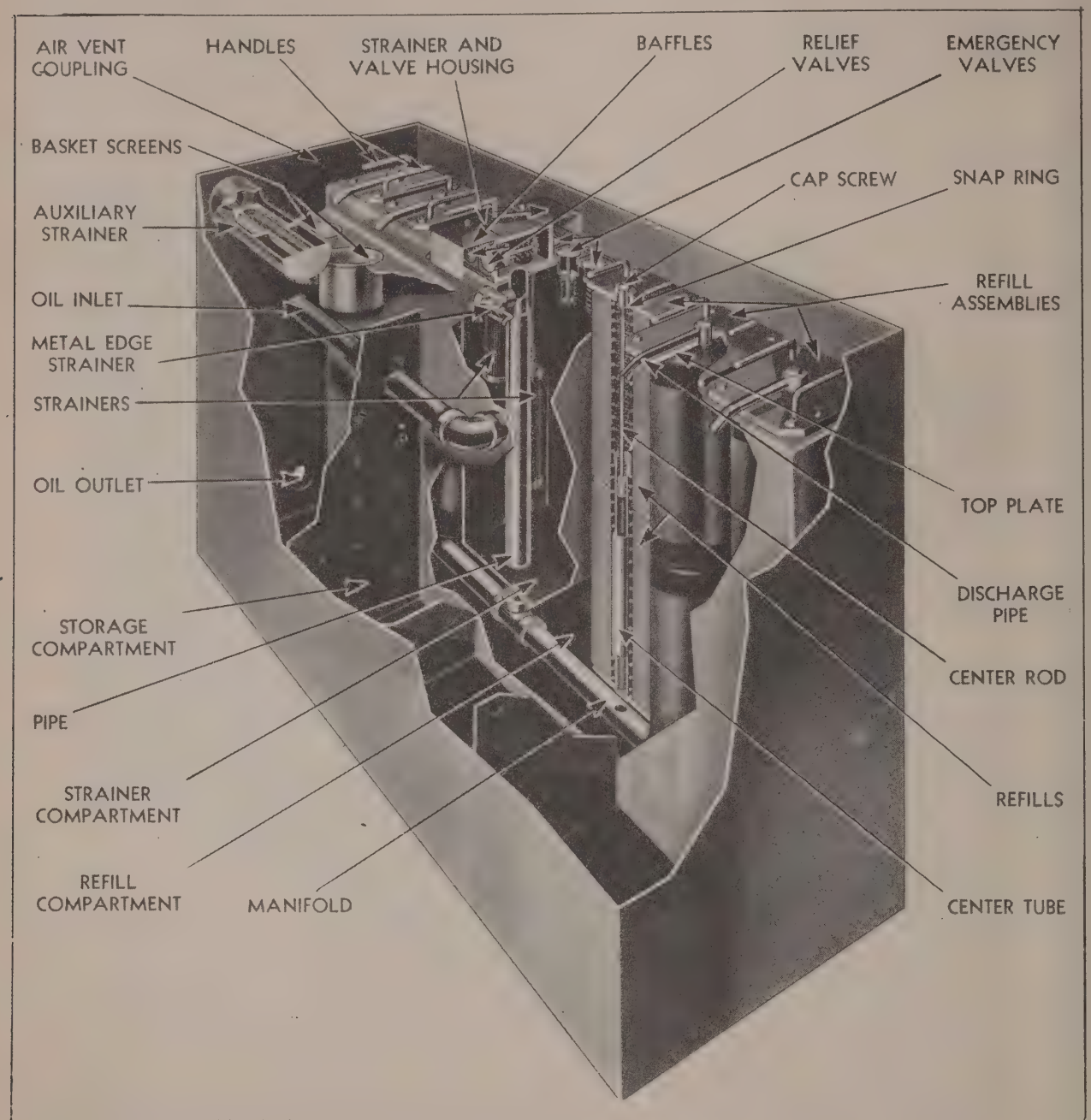


Fig. 6P
Sectional View of Filter

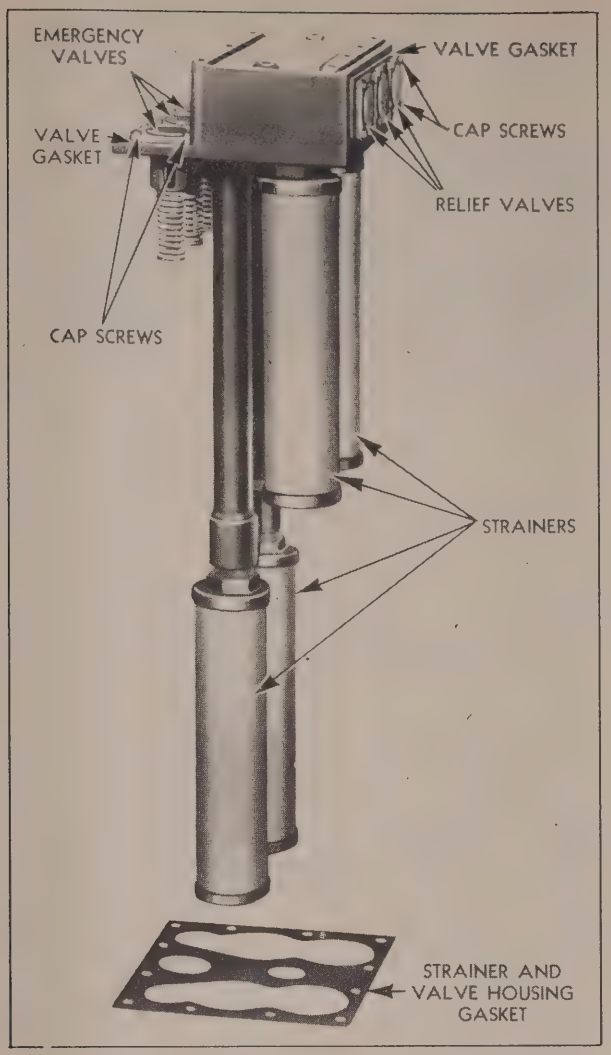


Fig. 7P
Strainer Assembly

shows a precipitation number of more than .05 or a neutralization number of more than .3.

Changing Refills.

1. Remove filter cover.
2. Remove stud nuts and lift out refill assembly.
3. Unscrew capscrew and lift off refill top plate.
4. Remove used refills and separator plate from holding assembly.
5. Clean all parts of the assembly.
6. Place one new refill over center rod and center on bottom plate.
7. Place separator plate over center rod and on refill.
8. Install second refill and align with separator plate and bottom refill.
9. Install top plate. Tighten capscrew to seal ends of refills.
10. Check top plate gasket.
11. Place refill assembly in filter and tighten top plate nuts to seal gasket.

If the pressure differential across the filter exceeds 25 pounds after new refills have been installed, the strainers should be removed and thoroughly cleaned.

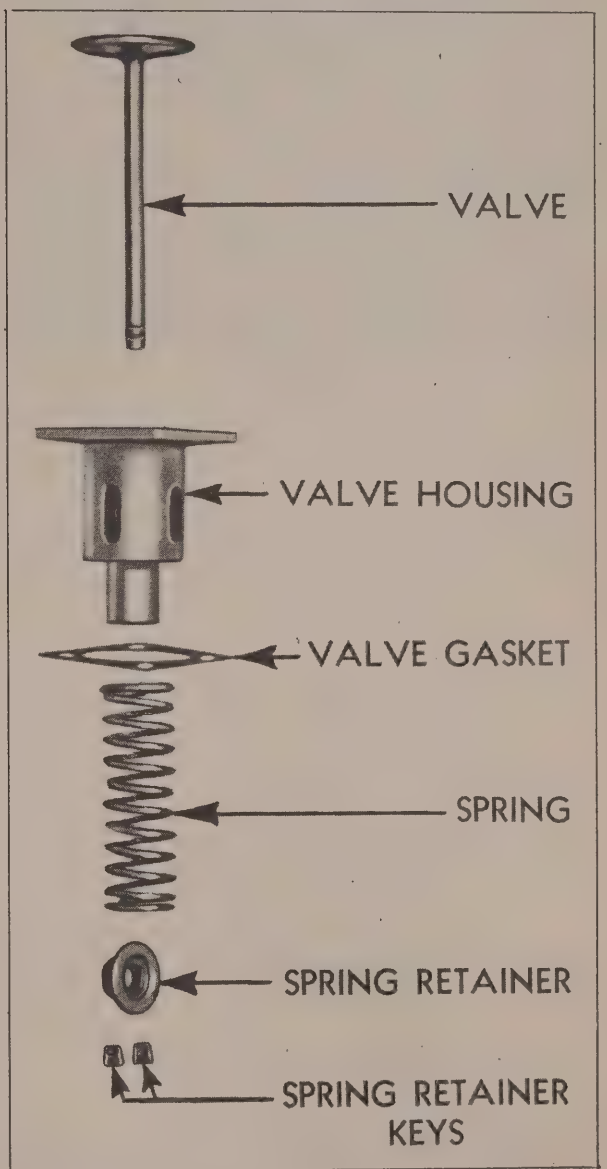


Fig. 8P
Relief Valve Assembly

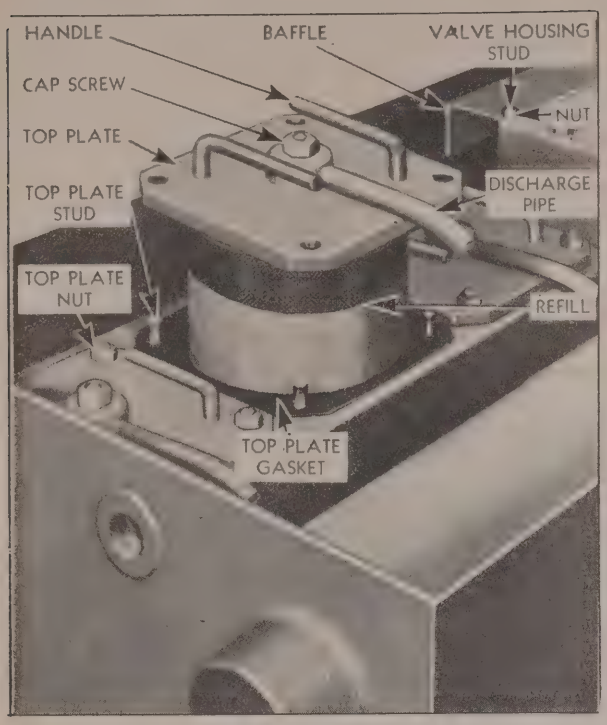


Fig. 9P
Top View—Refill Exposed

To clean strainers, remove the valve housing to which the strainers are mounted, from the filter tank. Wash strainers with a solvent until thoroughly clean. Check gasket and install valve housing with strainers in filter.

The scraper handle of the metal edge strainer incorporated in the upper section of the strainer compartment should be turned through several complete revolutions at frequent intervals to remove collected particles.

After installing refill assemblies or strainers, check storage compartment sight gauge and add oil to bring quantity to proper level.

Sludge, which settles to the bottom of the strainer and refill compartments, would be removed periodically through the sludge drains.

Lubricating Oil Cooler

Description. The oil cooler is made up of a cylindrical shell, a bundle of straight tubes held in place by a tube sheet at each end, and headers which are separated from the shell space by the tube sheets. The tube sheet at one end is clamped between the shell and the header. The tube sheet at the other end floats in a packed joint to allow the tube bundle to expand and contract in the shell. The sea water, used for cooling, passes through the tubes from one header to the other. The hot oil enters the shell at one end, flows transversely around the tubes and around the ends of the baffles, and leaves the shell at the other end. The sea water and oil flow through the cooler in opposite directions to produce the maximum cooling effect. Zinc electrodes are placed in the headers to centralize electrolysis.

Maintenance. To insure that the oil cooler is completely filled with sea water, the air vents on the tube side are opened. When the cooler is completely filled, the vents should be plugged and closed. This procedure is followed in filling the shell side of the cooler as well.

The oil cooler should be cleaned as soon as the cooling effect is materially reduced or the gauge pressures indicate that the flow through the cooler is restricted.

To clean the oil or shell side of the cooler, disconnect the pipe connections and drain the cooler thoroughly. Connect the shell connections to a closed galvanized steel storage tank containing carbon tetrachloride. By means of a pump, circulate the carbon tetrachloride from the center of the tank through the cooler and back to the bottom of the tank for a period of 20 to 30 minutes.

Drain the carbon tetrachloride from the cooler, remove the tube bundle from the shell and immediately hose the tube bundle carefully with warm water and blow it out with high pressure air over and through the tubes. The shell should be hosed with water and blown out with high pressure air.

The unit is then ready to reassemble, using new gaskets throughout, and should be connected, filled with oil, and started as described above.

The cleaning should be done in a room with adequate ventilation, or in the open air, to prevent any danger from the toxic effects of the carbon tetrachloride. Frequent wetting of the skin with this fluid should be avoided because the toxic effects are cumulative. Immersion of the hands in this fluid should also be avoided. Care should be taken to prevent mixing water with carbon tetrachloride because of the corrosive action of water floating on carbon tetrachloride.

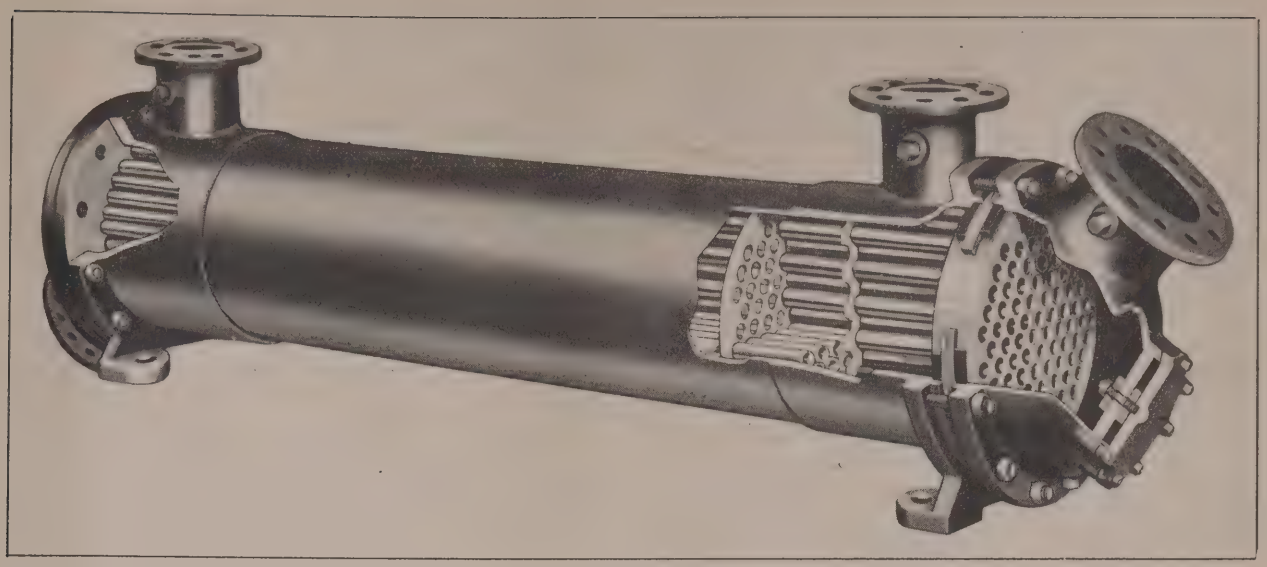


Fig. 10P
Lubricating Oil Cooler

Oil Pump Pressure Safety Valve

Description. A pressure safety valve, attached to the lubricating oil scavenging pump, prevents the lubricating oil pressure in the system from exceeding a safe operating pressure and is adjusted at the factory to relieve at 90 pounds per square inch. The safety valve consists of a cast bronze body containing a spring loaded poppet type valve. The adjusting screw is covered by a cap which screws on the safety valve body. The by-passed oil is returned to the suction side of the pump.

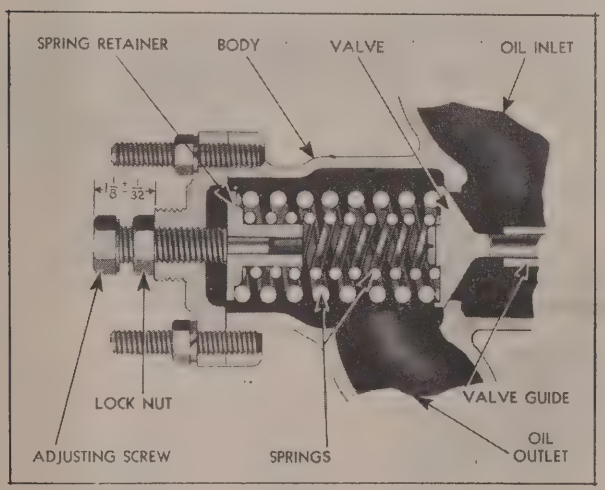


Fig. 11P
Lubricating Oil Pressure Safety Valve Adjustment

Adjustment. The pressure at which the safety valve operates is adjusted by removing the cover cap and loosening the locknut on the adjusting screw. When the distance from the head of the adjusting screw to the valve body is 1⅛" the valve is properly adjusted. (See Fig. 5P.) If the pressure at the strainer inlet is low and tightening the adjusting screw has no effect on the pressure, the strainer in the lubricating oil sump tank should be removed and cleaned and the lubricating oil should be inspected for fuel dilution.

Disassembly of Pressure Safety Valve.

1. Remove capscrews and lockwashers holding safety relief valve to lubricating oil scavenging pump and remove safety valve.
2. Remove adjusting screw cover and copper washer.
3. Back off adjusting screw to relieve pressure on spring.
4. Remove nuts and lockwashers holding head on body and lift off body cap carefully.
5. Pull out spring retainer and spring.
6. Remove pipe plug and push out valve.

Assembly of Pressure Safety Relief Valve.

1. Reverse disassembly operations. Use new gaskets if originals have been damaged.

Pressure Regulating and Relief Valve

Description. The pressure regulating and relief valve assembly is located on the camshaft drive housing cover below the throttle control lever. Its purpose is to regulate the pressure of the lubricating oil to the engine system. The assembly consists of two separate units in the same casting, the pressure regulating valve, and the pressure relief valve.

The regulating valve is connected to the injector linkage by a push rod which pushes against the inlet valve and seats it against the spill valve in the valve sleeve. The lubricating oil pressure then acts on the spill valve, forcing the spill valve to open slots in the sleeve and by-passing a portion of the lubricating oil to the camshaft drive housing. At idling speed, the inlet valve spring and the spill valve spring are relieved of compression so that the regulating valve operates at a low pressure, about 8 to 12 pounds. The oil pressure at the engine inlet increases with engine speed and load until the pressure is between 40 and 50 pounds per square inch at full load and speed.

The pressure relief valve prevents the lubricating oil at the engine inlet from exceeding 55 pounds per square inch. It consists of an adjustable spring loaded valve similar to the safety valve on the lubricating oil pump.

Adjustment. The pressure regulating valve is adjusted as follows:

1. Be sure injector racks are in stop position and adjust push rod clevis so that valves line up. (Be sure push rod is in its extreme out position before making adjustment.)
2. Start engine and run at idling speed with no load. Check lubricating oil pressure to engine and adjust regulating valve adjusting screw so that gauge shows a pressure of from 8 to 12 pounds per square inch. Tighten locknut.
3. With engine running at full load and full speed, the lubricating oil pressure should be between 40 and 50 pounds per square inch. If pressure is below 40 pounds per square inch, remove pressure relief valve cover and turn down pressure relief valve adjusting screw until oil pressure rises to a point where further adjustment no longer increases the pressure. Tighten locknut. Pressure should now be within the correct range. However, if it still has not reached 40 pounds per square inch, it will be

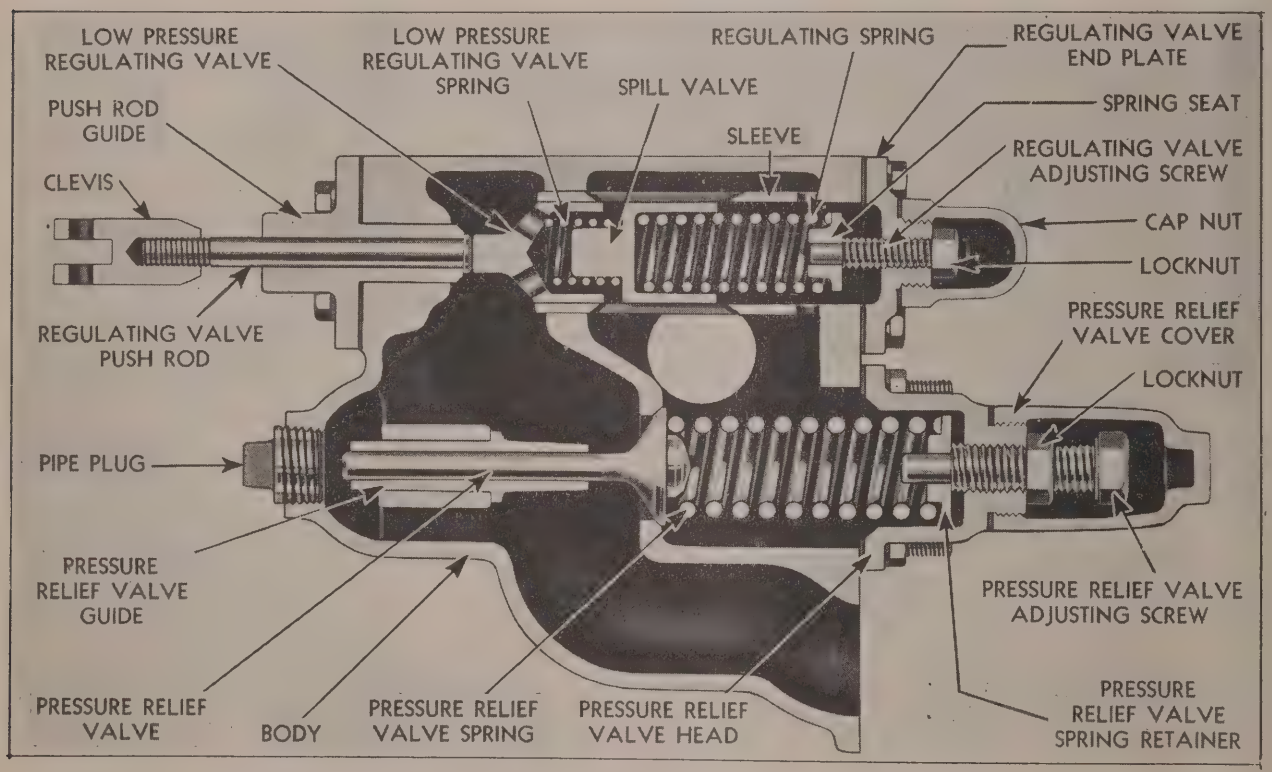


Fig. 12P
Lubricating Oil Regulating and Relief Valve

necessary to renew the springs in the regulating valve.

4. If, after step 3 has been completed, the lubricating oil pressure is above 50 pounds per square inch, it will be necessary to back off slightly on relief valve adjusting screw until 50 pounds per square inch is obtained.

Remove Pressure Regulating and Relief Valve.

1. Remove copper tubing connection to camshaft drive cover.
2. Remove lubricating oil line from engine inlet connection.
3. Remove regulating valve link to injector control.
4. Remove capscrews from pressure regulating valve bracket and pull off valve.

Disassembly of Regulating and Relief Valve.

1. Remove adjusting screw cover nut and copper washer of regulating valve.
2. Back off adjusting screw to relieve compression on spring.
3. Remove end plate.
4. Remove spill valve spring retainer, spring, spill valve, inlet valve spring, valve, and sleeve.
5. Remove valve guide and plunger assembly.

Disassembly of Relief Valve.

1. Remove adjusting screw cover nut and copper washer.
2. Back off adjusting screw to relieve compression on spring.
3. Remove valve head.
4. Remove spring retainer and valve spring.
5. Remove pipe plug and push out valve.

Assembly of Regulating and Relief Valve.

1. Reverse disassembly procedure.

Installing Regulating and Relief Valve on Engine.

1. Reverse removal procedure.

COOLING WATER SYSTEMS

Sea Water System

See Fig. 1R

The sea water pump draws sea water from the sea chest through a strainer and forces it through both the jacket water cooler and the reduction gear lubricating oil cooler, and out through the overboard discharge.

Fresh Water System

See Fig. 1R

The fresh water pump forces the fresh water to a manifold, located in the scavenging air chamber in each cylinder bank, and into the cylinder liners through a water connection at the lower deckplate in the engine cylinder block. The water is then forced upward into the cylinder heads through ferrules in the top of the liner, into the water jacket around the exhaust elbows, and into the water jacket around the exhaust manifold.

From the exhaust manifold the water is forced to the temperature regulator, which controls the amount of water that flows through the fresh water cooler. The water either is by-passed around the fresh water cooler or flows through it depending on the position of the temperature regulator valve. All of the water then flows through the lubricating oil cooler and back to the suction side of the fresh water pump.

An expansion tank located at the highest point of the fresh water system acts as a reservoir. A pipe from the expansion tank to the suction side of the fresh water pump serves as a make-up and fill line for the otherwise closed cooling system. A vent line, from the highest point of the piping to the expansion tank, keeps the system free of air, thereby preventing the fresh water pump from becoming air bound, which would result in excessive water temperature.

Fresh and Sea Water Pumps

See Fig. 2R

Description. The pumps are of the centrifugal type. The water enters the center of the impeller and is thrown outward through the impeller vanes by the rotation of the impeller.

The impeller is keyed to the tapered end of the driving shaft and rotates in the pump housing on two bearings on either side of the impeller vanes. Each bearing is composed of two replaceable bronze rings, an impeller ring and a casing ring. The shaft sleeve is keyed to the shaft and butts against the impeller. A water-tight seal between the shaft and the shaft sleeve is formed by a small packing ring that fits into a recess in the end of the sleeve. This packing is compressed by screwing the locking sleeve toward the impeller with a spanner wrench. The locking sleeve compresses the packing between the shaft sleeve and the shaft and is locked in place with a setscrew. The setscrew must be loosened before the locking sleeve can be tightened. The gland must be removed to gain access to the setscrew.

A flinger is locked to the shaft with a setscrew and throws off any water that might have worked its way along the shaft toward the ball bearing. The ball bearing is pressed on the shaft and can be removed only with the bearing puller furnished for this purpose. This bearing is lubricated by splash lubrication from the accessory drive. A leather seal prevents the oil from leaking out of the housing.

The fresh and sea water pumps are not interchangeable between right-hand and left-hand rotation engines.

Maintenance. When adjusting the outer packing gland, pull up the nuts evenly while the engine is running. Always allow a slight leakage to lubricate the packing. A gland pulled up too tightly will cause excessive wear of the packing and shaft sleeve, and will increase the power consumption.

When the pump leaks excessively, and the leakage cannot be stopped by pulling up lightly on the outer gland nuts, the outer packing gland should be removed, the setscrew in the locking sleeve removed, and the locking sleeve tightened. Replace the setscrew. Repack the outer stuffing box.

The casing and impeller rings should be renewed when the clearance between them is 0.060″.

To Repack the Stuffing Box.

1. Carefully clean stuffing box of dirt and particles of old packing.
2. Dip each ring of packing in oil and put one ring in at a time, pushing it well into place. The joints of succeeding rings must be staggered.
3. After the last ring of packing has been installed

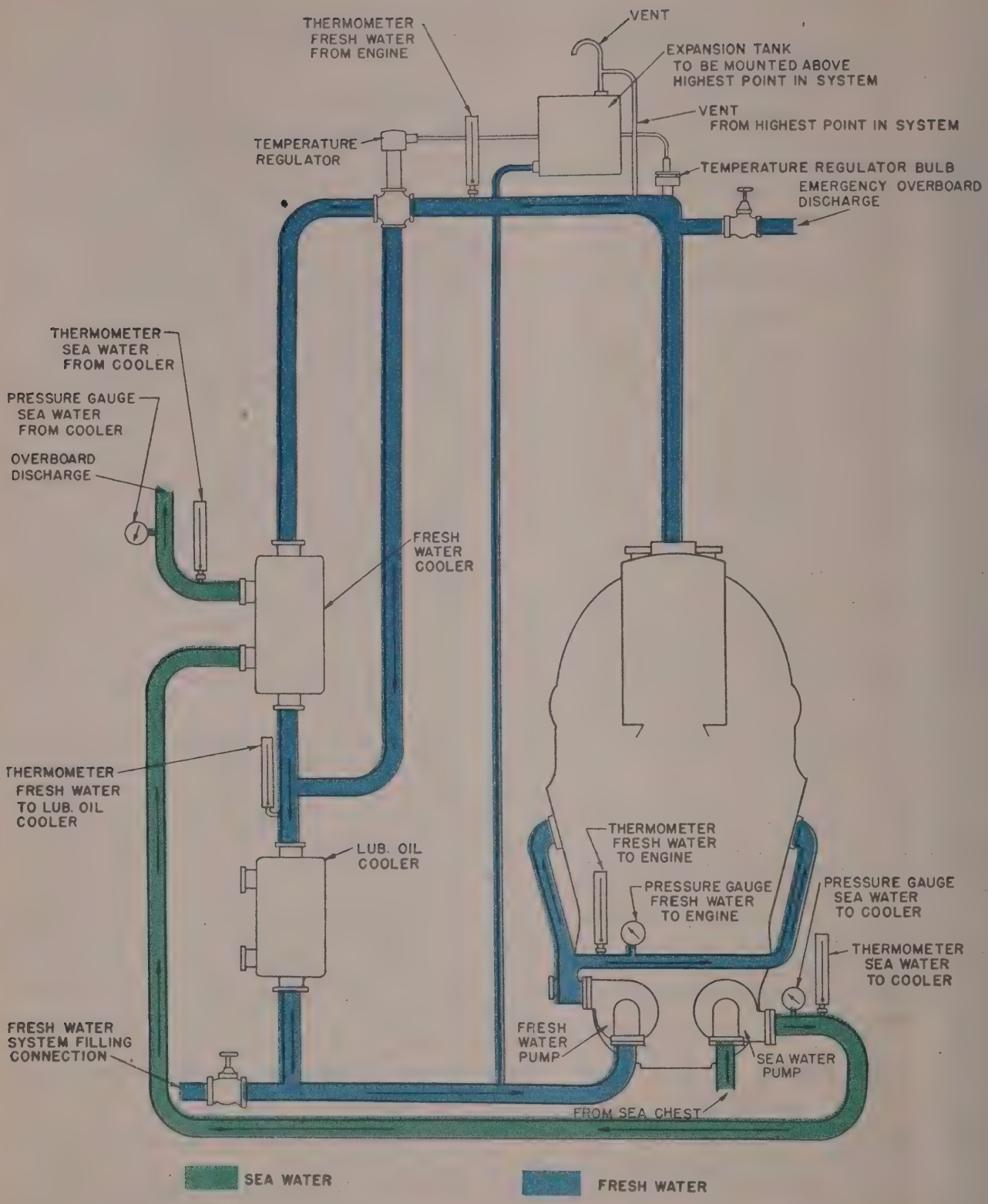


Fig. 1R
Fresh and Sea Water Systems

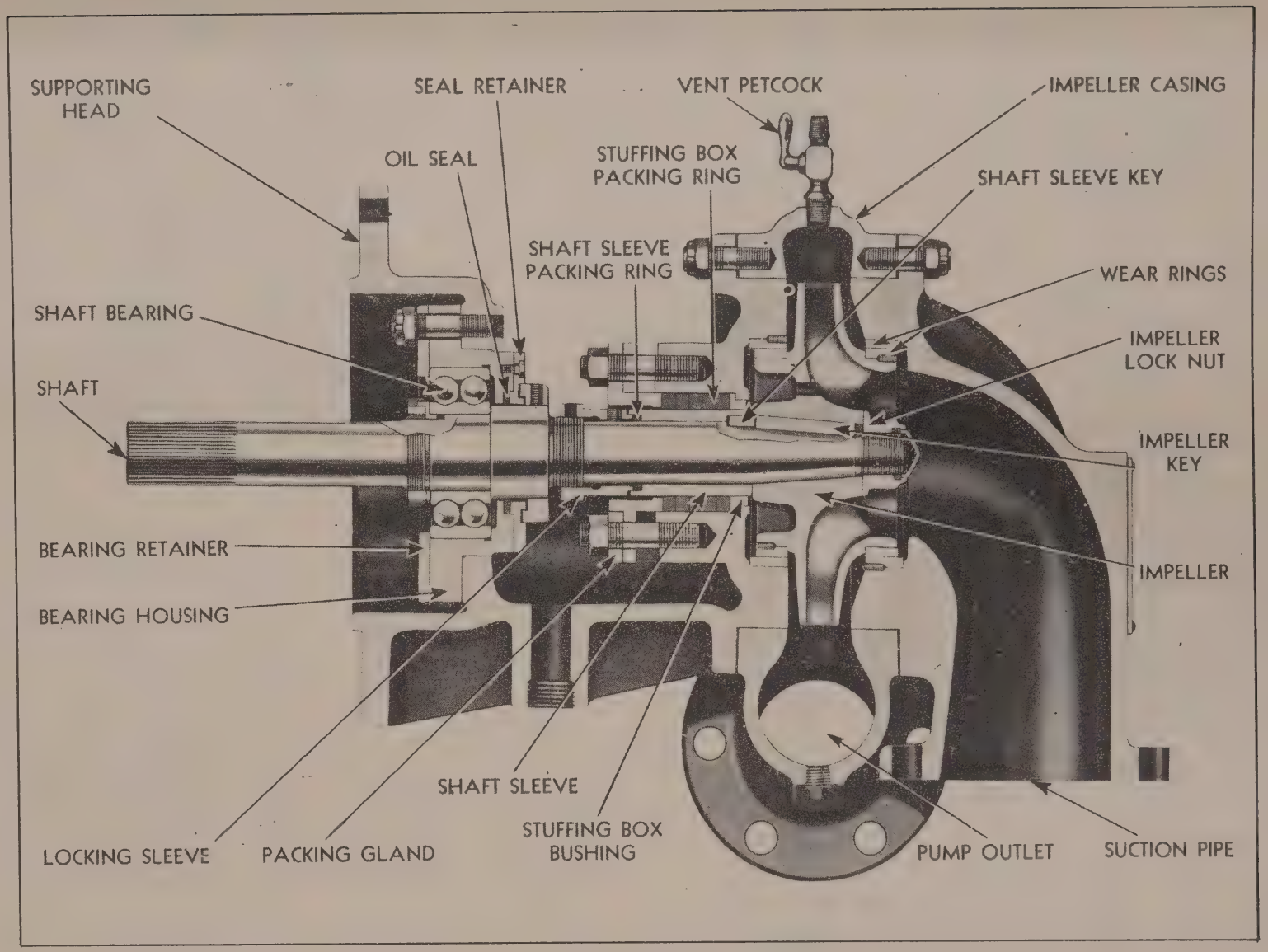


Fig. 2R
Water Pump Cross Section

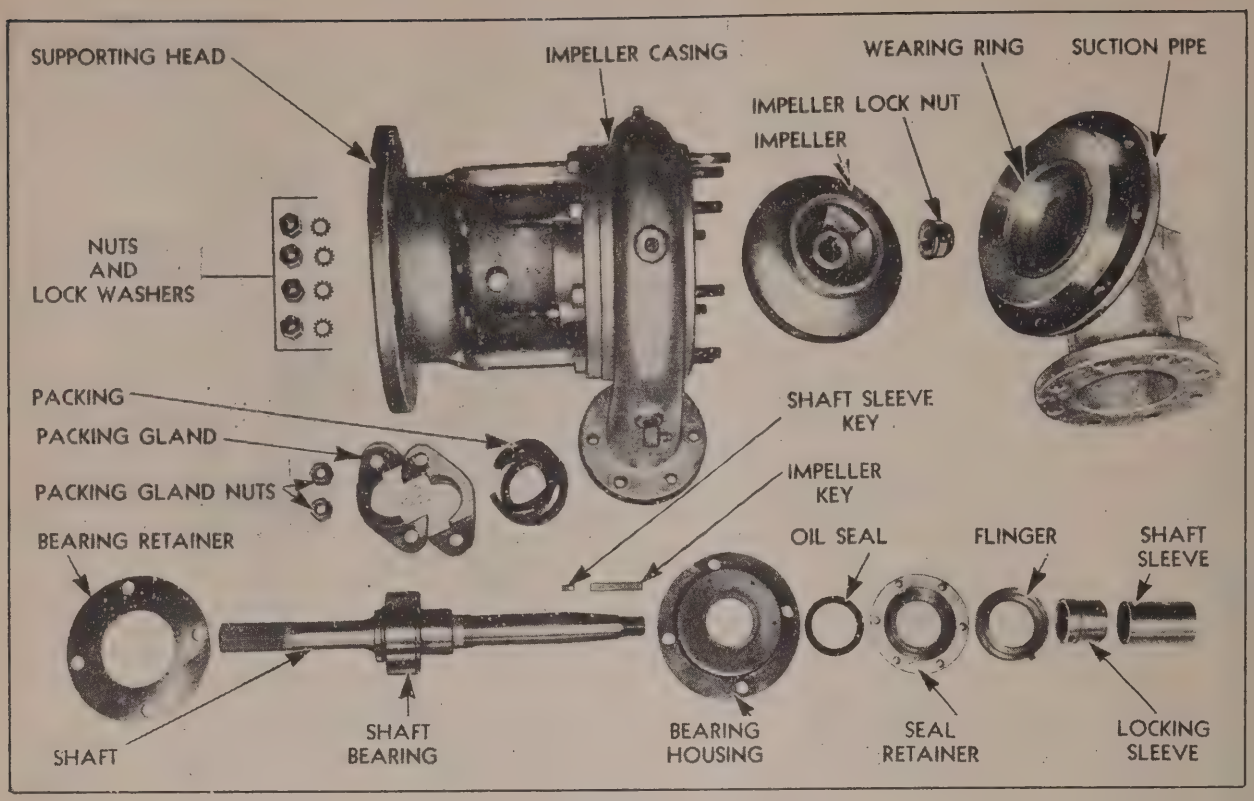


Fig. 3R
Water Pump Exploded View

install gland and draw up the gland nuts evenly until snug, then back off the nuts and tighten again with the fingers only. After the pump has been run it may be necessary to readjust the gland.

To Replace the Wearing Rings.

1. Disconnect suction piping and remove nuts holding suction flange to pump casing. Remove flange.
2. Remove impeller nut and pull off impeller. (See "Disassemble Water Pumps" page R-5.)
3. Remove screw pin holding rings in place on impeller and in casing.
4. Machine rings from their seats.
5. The replacement rings must be machined so that there will be a 0.003″ to 0.008″ press fit between the impeller rings and the impeller and between the casing rings and the casing. The rings are then shrunk into place. The clearance between the impeller rings and the casing rings should be 0.030″ to 0.035″.

Note: It may be necessary to remove the pump from the engine to perform the above operations.

Remove Fresh and Sea Water Pumps.

1. Remove connecting lines.
2. Remove nuts and capscrews holding water pump bracket and remove bracket.

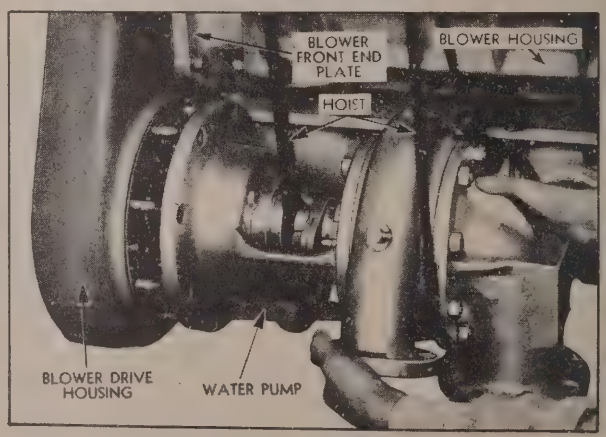


Fig. 4R
Removing Water Pump

3. Remove nuts from water pump flange studs.
4. Attach hoist to pump and lift slightly to take strain from studs.
5. Pry pump loose from dowels and pull from drive gear.

   If water pump does not pull out easily after pump flange is free of dowels, proceed as follows:

   a. Remove nuts from pump gear bearing cover on accessory drive housing cover and remove bearing cover and paper gasket. Be sure cover and housing are match-marked before removing cover.

   b. Drive water pump shaft out of drive gear using brass rod on end of shaft.

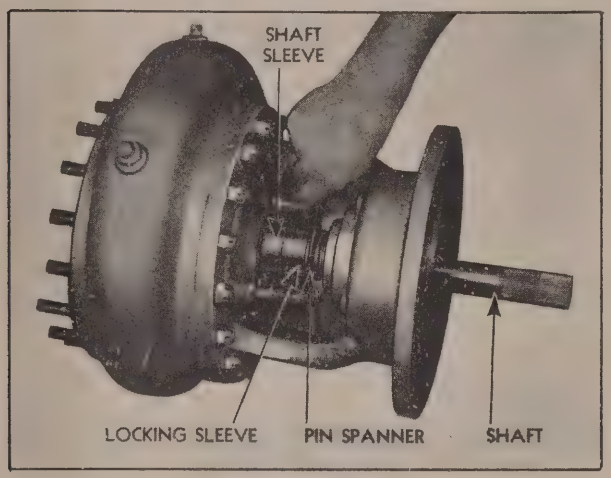


Fig. 5R
Removing Water Pump Impeller

Disassemble Water Pumps.

1. Remove suction pipe.
2 Remove nuts holding split packing gland and remove gland.
3. Remove impeller locknut.
4. Loosen setscrews in locking sleeve and flinger using Allen setscrew wrench.
5. Block pump shaft against rotation and screw locking sleeve against shaft sleeve with spanner wrench to jack impeller off pump shaft. Lift off impeller and key.
6. Remove nuts holding bearing cover plate and bearing housing to pump supporting head.
7. Pull shaft from drive end. The bearing, bearing housing, seal retainer, flinger, locking sleeve, and shaft sleeve will remain on shaft.
8. Remove shaft sleeve and key, locking sleeve, flinger, seal retainer, and bearing housing from shaft.
9. Remove bearing retaining collar and lockwasher. Attach bearing puller and remove bearing.

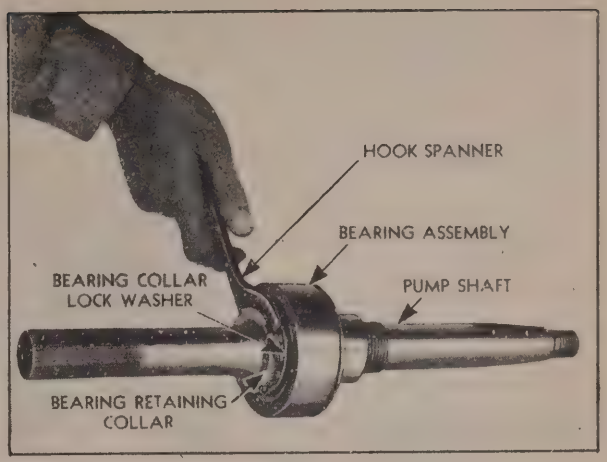


Fig. 6R
Removing Bearing Retaining Collar

Assemble Fresh and Sea Water Pumps.

1. Reverse the procedure used in disassembly.

Install Fresh and Sea Water Pumps.

1. Inspect spline shafts on pumps for nicks or burrs. Clean up with file.
2. Reverse procedure used to remove pumps. Use new gaskets if any have been damaged.
3. When replacing pump gear bearing cover on accessory drive housing cover be sure match-marks line up.

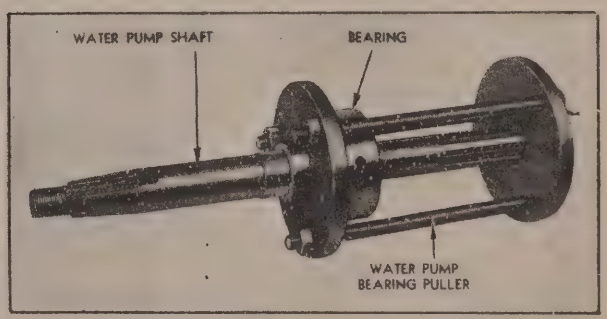


Fig. 7R
Removing Bearing from Pump Shaft

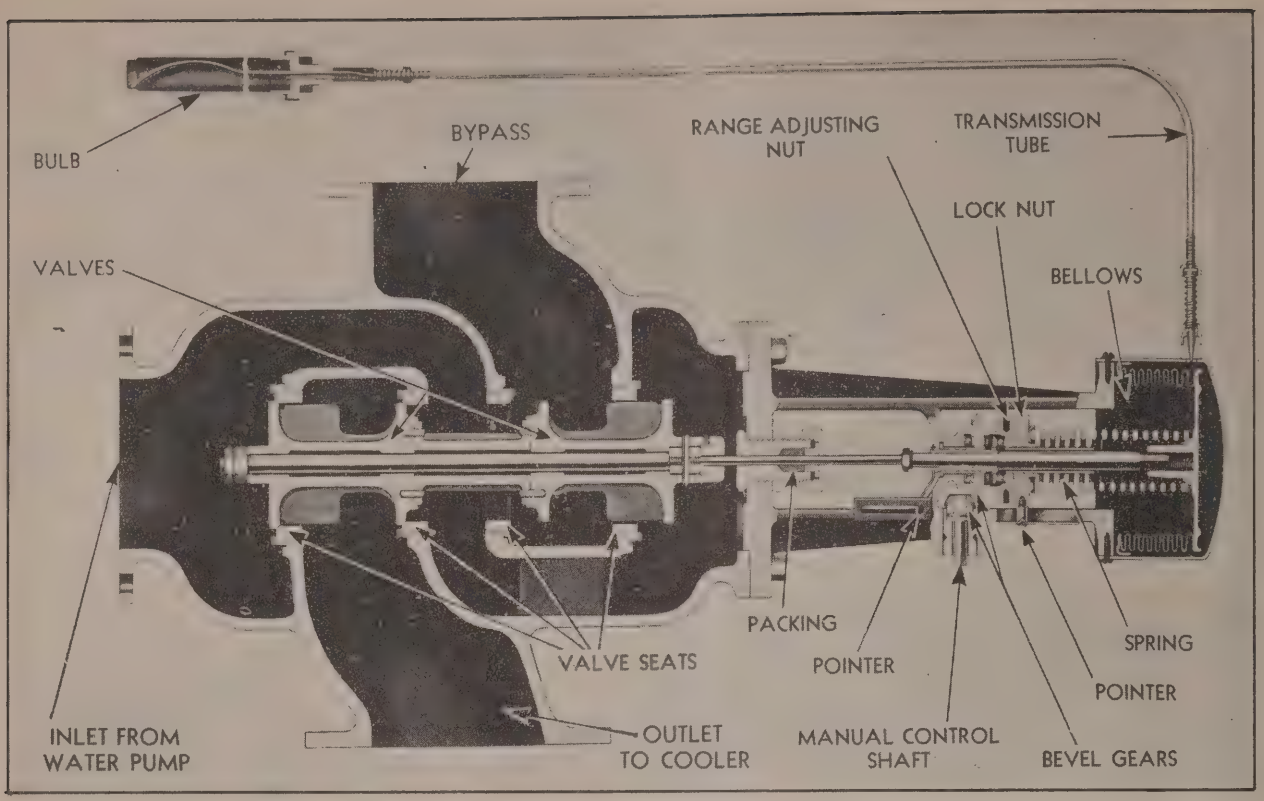


Fig. 8R
Temperature Regulator

Fresh Water Cooler

The engine water is cooled in a Harrison type cooler, which consists of two core assemblies, each with an enclosing case. The two sections are bolted together. The oblong tubes in each section are baffled to form tortuous passages for the flow of engine water. The tubes are fastened to header plates at the ends. Each core assembly is permanently attached to its casing.

Maintenance. The fresh water cooler should be cleaned as soon as the temperature of the fresh water discharged from the engine exceeds the allowable maximum. After all other possible causes of high fresh water temperature have been investigated, the cooler is removed from the engine, and the end covers removed. The cooler should then be cleaned.

The cooler is equipped with sixteen zinc plates in the sea water passage, preventing electrolytic action on the tubes. Two plates are attached to each of the small covers located at the inlet and outlet and on the bottom of the cooler.

Zinc electrodes should be examined thirty (30) days after installation and every thirty (30) days thereafter. Any appreciable deterioration within these periods indicates electrolytic action, caused by external grounded electric currents. In that case this condition must be corrected to avoid serious damage to the cooler. Internal electrolysis causes a gradual eating away of the electrodes, necessitating periodic renewal.

Inspection may show that the zincs are coated with insulating foreign materials. These must be removed by wire brushing and scraping before reinstalling zincs. Zincs should be renewed when 50% disintegrated.

Frequency of Cleaning. The cooler should be cleaned as frequently as found necessary to provide unrestricted flow of water. This will vary, depending on operating conditions. After one or two inspections the operator will be able to determine the length of time necessary between regular periodic cleanings of the cooler.

In certain types of service deposits form more

rapidly than others. Heavy deposits cause an objectionable increase in pressure drop through the cooler, and a decrease in the cooling effect. Cleaning at regular intervals will insure maximum operating efficiency at all times.

Both sides of the cooler should be cleaned whenever the unit is disconnected for cleaning. No wires or prods which would damage the internal structure of the tubes should be used in the cleaning operation.

Cleaning Fresh Water Cooler. Remove all zinc electrodes first, then immerse cooler in a solution composed of one-third (⅓) muriatic (commercial hydrochloric) acid and two-thirds (⅔) water, to which has been added one-half (½) pound of oxalic acid for each two and one-half (2½) gallons of solution. Remove cooler when foaming and bubbling stops. This usually takes from thirty (30) to sixty (60) seconds. Immediately pressure flush *thoroughly* with clean hot water. Remove all foreign substance from inside covers and casing before reassembling. Clean all gasket surfaces thoroughly and use new gaskets wherever necessary.

Temperature Regulator

The fresh water in the engine is maintained at a uniform temperature by the temperature regulator, which controls the amount of fresh water flowing through the fresh water cooler. (See Fig. 8R.) When the fresh water temperature is higher than the temperature for which the regulator is adjusted, the regulator valve is actuated to increase the flow of fresh water through the cooler. When the engine water temperature is lower than the temperature for which the regulator is adjusted, the valve increases the flow of fresh water through the cooler.

The temperature regulator, consisting of a valve, valve operating mechanism, and temperature control bulb, is installed in the engine cooling system to control the engine water temperature. The bulb, mounted in the jacket water discharge connection from the engine on the exhaust manifold, is connected by means of a flexible, armored tube to the regulator bellows.

The temperature regulator is automatic, but provision is made for manual operation should the automatic system fail in service.

Vapor pressure in the bulb, generated by heat on it, forces liquid through the flexible tube providing liquid power transmission to the regulator piston.

The regulator operates only within the temperature range marked on the nameplate, and may be adjusted for any temperature within this range. The setting is controlled by the range adjusting nut which is located under the spring seat. The pointer which is attached to the spring seat indicates the temperature on a scale attached to the regulator frame. The scale is graduated from 0 to 9, representing the total operating range of the regulator.

Compare the temperature setting of the regulator with the thermometer reading of the fresh water flowing from the exhaust manifold. If necessary, the temperature may be changed by means of the range adjusting nut. A few minutes are required after each adjustment to allow the hot jacket water to act on the bulb.

The temperature regulator can be manually controlled by turning the square end shaft projecting from the side of the unit. This operates the regulating valve spring through a pair of bevel gears and a threaded sleeve. A pointer, attached to the threaded sleeve, indicates the valve position. When the pointer is in the "Closed" position nearer the valve, the valve is set to allow all of the fresh water to be pumped directly through the water cooler. When the pointer is in the "Thermostatic" position, it indicates that the unit is controlled completely by the automatic system as described. When the pointer is in the "Closed" position nearer the bellows, it indicates that all of the fresh water is being by-passed around the water cooler, and flows directly to the lubricating oil cooler. For automatic operation the pointer must be set at the thermostatic position.

Maintenance. For the proper operation of the temperature regulator, the valve stem must not bind in the stuffing box, but must move freely. The valve stem should be lubricated frequently where it enters the stuffing box and also around the threaded sleeve used for the manual control. A small amount of cup grease should be used on the bevel gears.

The valve packing nut should be kept only finger tight and should be lubricated occasionally with a drop of oil. Should it become necessary to renew the packing, remove the nut, taking out the packing gland, and then clean out the stuffing box and repack with a good grade of asbestos wicking saturated with oil.

Should the temperature of the fresh water leaving the engine be too high with the lowest adjustment setting, check as follows:

1. Make sure manual pointer is set at the "Thermostatic" position.

2. Make sure packing gland is not binding valve stem, and valve is not otherwise stuck in the minimum cooling or closed position.

3. Check sea water and fresh water lines for other source of difficulty. If this does not reveal trouble, it is probable that the thermostat is inoperative, and should be checked. If defective, it should be renewed.

If undercooling is experienced at highest adjustment setting, check for sticking valve in maximum cooling position. This may be caused by a tight stuffing box or by dirt under lower valve seat.

AIR INTAKE AND EXHAUST SYSTEM

General Description. An air blower scavenges the engine cylinders by forcing air through the intake ports in the liners as the pistons approach the end of the power stroke. This air also scavenges the cylinders of burned exhaust gases through the open exhaust valves in the cylinder head.

Air is drawn by the blower through an intake silencer and is discharged into the air box surrounding the cylinders. Air is admitted to each cylinder when the piston uncovers the intake ports. These ports are designed to produce a swirling flow of air upward through the cylinder toward the exhaust valves which open for the discharge of the exhaust gases. This results in complete scavenging and filling of the cylinders with clean air.

Blower

General Description. The blower consists of a pair of rotors revolving together in a closely-fitted housing. Each rotor has three helical lobes which produce a continuous and uniform displacement of air. The rotors do not touch each other or the surrounding housing. Air enters the housing at the top and fills the spaces between the rotor lobes as they roll apart. The air is carried around the cylindrical sides of the housing, in the closed spaces between the lobes and the housing, and is forced under pressure to the bottom of the housing as the lobes roll together. Then the air passes through the space between the inner and outer wall of the blower housing and into the air box around the cylinder liners.

Each rotor is carried by a tubular serrated shaft. Endwise movement is prevented by two taper pins.

No gaskets are used between the end plates and the housing due to the importance of maintaining the correct rotor end clearance. A fine silk thread around the housing, inside of the stud line, together with a very thin coat of non-hardening gasket compound, provides an air-tight seal.

Large babbitted bearings in the end plates accurately locate the rotors in the two half bores of the housing, so that the clearances between the rotor tips and the housing bores can be held to a minimum. Both ends of the rotor bearings at the gear end of the blower are made with thrust surfaces which locate the rotors endwise and prevent contact between the rotors and the end plates.

The power to drive the blower is transmitted directly to the rotor gear train by a drive shaft which extends through a passage in the blower housing. Closely-fitted helical rotor gears are rigidly attached to both rotor shafts to prevent the rotors from touching each other as they roll together. Each hub is pressed on the serrated rotor shaft. A hexagon head lockscrew, threaded in the rotor shaft, holds a thrust collar as a spacer between the gear hub and the end of the rotor maintaining the clearance between the rotors and the blower end plate.

The blower rotor gears are bolted to the gear hub flanges and are located angularly by hardened dowel pins. Due to the importance of having the rotors roll together without touching, yet with the least possible clearance, it is necessary to locate the dowel pins during assembly for a given set of gears and hubs. This is the only adjustment provided for timing the gears with respect to the rotors.

Oil passages in the end plates conduct lubricating oil under pressure to the bearings. Oil seals are provided at each bearing to prevent oil from entering the rotor housing.

Operating Troubles. The principal causes of blower trouble can be classified into three groups:

1. Foreign matter drawn into the air inlet.
2. Excessive wear of the parts.
3. Failure due to insufficient lubrication.

Damage caused by foreign material entering the blower may result in the rotors striking each other or the housing, and is indicated by a bumping or clicking noise. Such a sound should be investigated immediately because continued operation may result in serious scoring of the surfaces that are rubbing.

The blower should never be operated without a suitable screen to protect the air inlet. While changing air silencers, or while working on the engine, care must be taken to keep the inlet to the blower covered at all times. If the blower is to be stored or shipped, a suitable heavy cover should be bolted to each of the housing openings.

The gears and the thrust bearings are moderately loaded. Determine their rate of wear from the

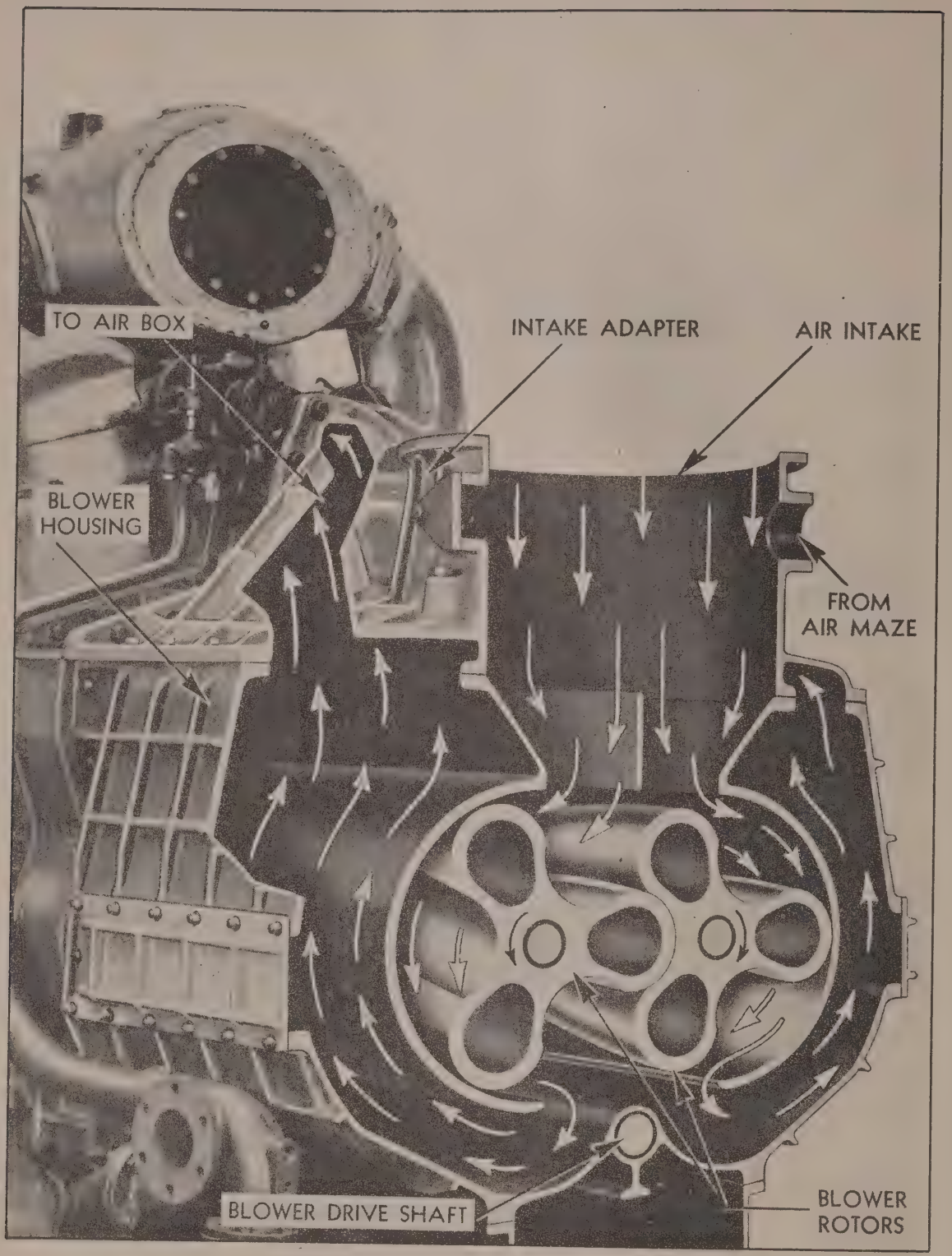


Fig. 1S
Blower Assembly

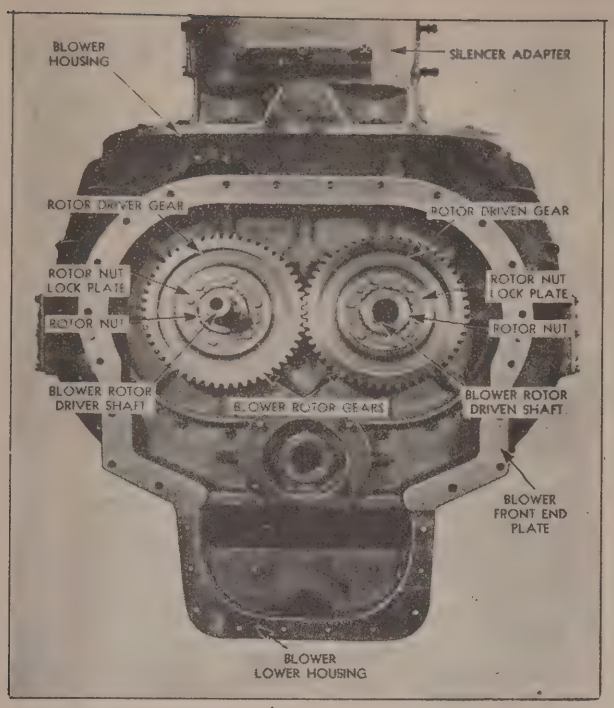


Fig. 2S
Front View of Blower

results of the periodic inspections and records. They should be renewed before rotor interference begins.

With the pressure lubricating system, there should be no failure in the oil circulation unless some of the oil passages become obstructed.

Inspection. The intake silencer and the air intake adapter are removed to inspect the rotor housing. Any interference between the rotors themselves is seen near the pitch line of the lobes. Scratches in the housing bores or on the rotors are caused by dirt and, generally, are not serious. During this inspection, care must be taken to prevent the entrance of foreign material into the rotor housing.

The efficiency of the blower depends on how small the clearances can be maintained in service. Periodic inspection will indicate the rate of wear and when the worn parts should be renewed to prevent rotor interference. The parts most likely to wear and cause rotor interference are the timing gears and the thrust bearings.

During the periodic inspection the accessory drive gear train cover and housing should be removed, and the rotor gear backlash measured with a feeler gauge. The observed rate of increase in gear backlash will determine if the rotor gears will perform satisfactorily until the next inspection period. For a normal blower, the total backlash in the rotor gears may become approximately 0.010″ before any adjustment is necessary. When this backlash is exceeded the rotor gears should be renewed.

The rotors are pried endwise, forward and back, and the clearance between the rotors and the end plates is measured with a feeler gauge. When this clearance is less than 0.003″ the thrust bearings should be renewed.

The clearance between the rotor lobes should be checked at the same time that the end clearance is checked. With new rotor gears and thrust bearings the clearance between the rotor lobes should measure approximately 0.024″ at the leading edge and 0.016″ at trailing edge. See "Timing Blower Rotors," below.

Renewals. Each blower unit is individually timed when it is first assembled, because it is not practical to machine the gears and rotors with a fixed, angular relationship. Both rotor gears should be renewed when they have worn to such an extent that further wear is likely to cause rotor interference. The rotors should be carefully retimed with the proper clearance when the rotor gear, gear hubs or rotors are renewed.

Timing Blower Rotors. When new blower rotor gears or hubs are installed it is necessary to retime the rotors.

1. After blower rotors are assembled in housing,

Fig. 3S
Checking Rotor End Clearance

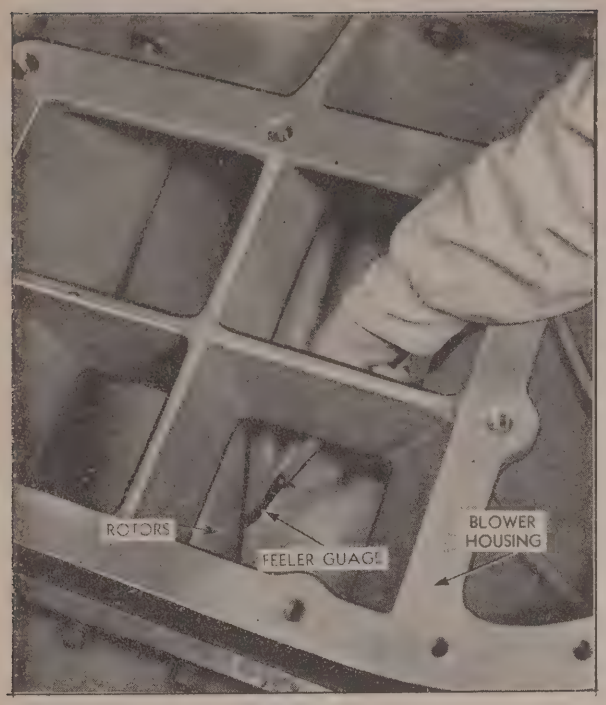


Fig. 4S
Checking Rotor Lobe Clearance

and end plates secured in place, turn blower rotors so that match-marks on shafts face each other.

2. Place drive gear over drive shaft and on hub so that match-mark on gear is as close as possible to being in line with match-mark on rotor shaft. Insert capscrews and tighten.

   Note: There should be no shim between hub and gear.

3. Place driven gear on its hub. Match-marked teeth on driven gear and drive gear must mesh. Insert capscrews and tighten.

4. Using long feeler gauge as shown in Fig. 4S, adjust clearance between blower rotor lobes to 0.018″ to 0.020″ by loosening capscrews, rotating rotors relative to the gears. Tighten capscrews when correct clearance has been obtained. Rotors must be turned in normal direction of rotation to avoid error due to gear backlash.

5. Remove rotor shaft nuts. Pull both gears and hubs at the same time with suitable gear pullers, Drill and ream dowel pin holes on gears and hubs.

6. Disassemble gears from hubs and reassemble in blower as described under "Assemble Blower," steps 8 through 14.

   Note: The addition of the 0.010″ shim between drive gear and hub will alter clearance between rotor lobes to approximately 0.024″ at leading edge and 0.016″ at trailing edge.

Removing Blower Assembly

1. Remove fuel oil strainer and filter. (See Section N.)
2. Disconnect fuel oil supply and bleed lines at manifolds and remove lines.
3. Remove intake silencer.
4. Remove blower intake silencer adapter.
5. Remove accessory drive assembly. (See Section K.)
6. Insert pipe through water line holes in lower blower case, attach hoist to ends of pipe and hold in position.
7. Remove capscrews holding lower blower case to blower housing and engine base.
8. Lower the lower blower housing free with hoist.
9. Remove blower drive gear bearing oil line from bottom of blower housing end plates and lubricating oil manifold.
10. Remove castellated nuts inside blower case.
11. Attach hoist, remove capscrews, nuts and bolts, and remove blower, being careful not to damage studs. Place blower on blocks in same position as when blower is mounted.

Disassemble Blower.

1. Remove Allen screw from blower rotor nuts at engine end of blower. Mark each setscrew so that it can be returned to its original place.
2. Remove blower rotor nuts with large Allen wrench.
3. Bolt suitable wood strip to retain oil seals and sleeves. (Remove sleeves and leather seals only if they have been damaged and must be renewed.)
4. Attach hoist and place blower on end, with the drive gears up.
5. Remove nuts from outer flange of front end plate.

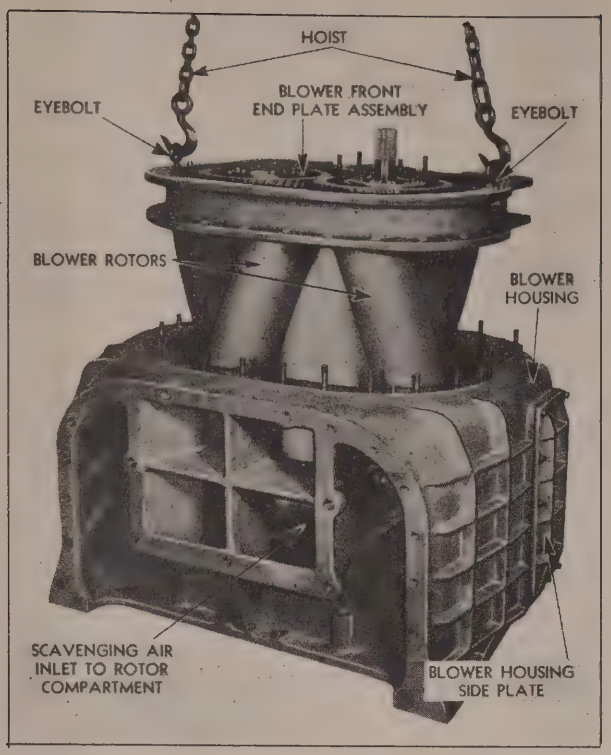


Fig. 5S
Removing Rotors from Housing

6. Remove castellated nuts from inside of front end plate.
7. Attach eyebolts to front end plate, attach hoist and lift out rotors and front end plate assembly. Be very careful that rotors do not strike sides of housing.
8. Place rotor and front end plate assembly on wood blocks with gears up.
9. Remove lock plates from each gear.
10. Pull the two dowel pins in each gear by the washerstack method and remove gears and thin shim under drive gear.
11. Remove nuts on rotor shafts using large socket wrench.
12. Pull blower gear hubs from shafts with suitable puller.
13. Lift front end plate from rotor shafts.
14. Remove castellated nuts from bearing flanges in the front end plate.
15. Insert jackscrews in holes provided in bearing flanges and jack out bearings.
16. Remove leather oil seal and sleeves by hand. (Remove only if seal has been damaged and must be renewed.)

Assemble Blower.

1. Be sure all parts of blower and tools used in assembling are free from dirt, lint, and burrs. Use no oil on inside of case or on rotors. Wash with solvent and blow out with air.
2. Insert leather oil seal with feathered edge out.
3. Care must be taken in replacing the sleeve so that the oil seal fits properly. A pilot of the same diameter or slightly larger is inserted through the seal from the back and the sleeve pushed in from the front, forcing the pilot out and inserting the sleeve at the same time.
4. Press blower shaft bearings into front end plate over studs and replace nuts and cotter pins.
5. Inspect blower rotors for nicks or burrs, and smooth with emery cloth. Wash with solvent and blow off with air.
6. Place blower rotors on blocks and time by facing the missing serrations on each rotor shaft toward each other.
7. Place front end plate over blower shafts care-

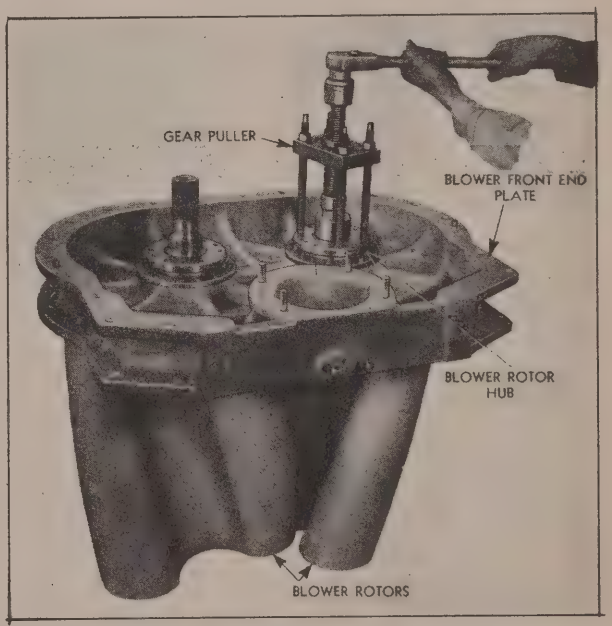


Fig. 6S
Removing Rotor Gear Hubs

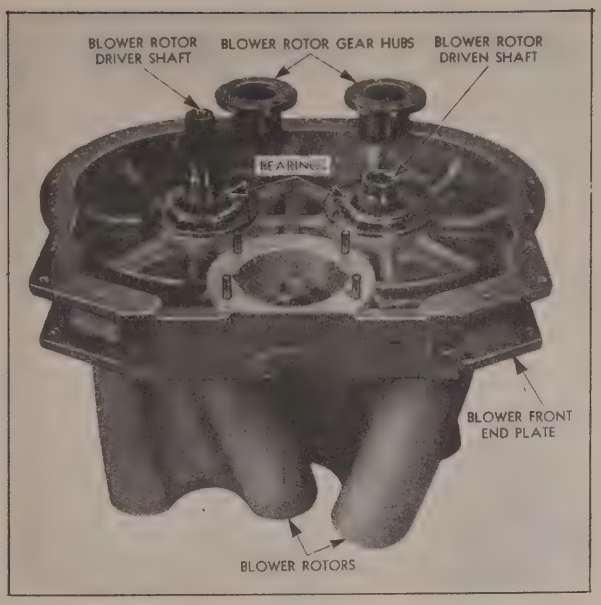


Fig. 7S
Rotor Gear Hubs Removed

fully so that the ends of the rotors and splines are not damaged.

Note: Be sure to place the front end plate so that the long rotor shaft extends through the bearing marked "DRIVER."

8. Place shaft hubs on shafts with wide serrations in hubs lining up with missing serrations on blower shafts.
9. Using suitable tool, seat gear hubs on blower shafts.
10. Replace and tighten blower rotor shaft nuts.
11. Turn drive shaft so that match-mark on shaft is toward the driven shaft, place thin shim on hub and line up holes.
12. Place driving gear on shaft so that match-mark on gear lines up with same mark on shaft. Insert and drive the dowels.
13. Place driven gear on shaft so that match-mark faces match-mark on driving gear and drive dowels.
14. Place lockplates on both gears, insert, tighten and lockwire capscrews.
15. Paint front end face of blower with a film of "Perfect Seal," thin out with fingers, and lay number 50 silk sewing thread on the seal smeared surface (this acts as an air seal gasket).
16. Attach eyebolts and hoist to front end cover and lower assembly into blower housing carefully. Do not allow the rotors to strike the housing.
17. Install castellated nuts inside blower front end plate and tighten, install flatwashers, lockwasher, and nuts around front end plate flange, and tighten. Cotter castellated nuts.
18. Attach hoist and turn blower to same position as when mounted.
19. Install leather seals in rear end plate and reinstall sleeves using pilot.
20. Re-install blower rotor nuts which were marked, at disassembly, to their respective shafts. Tighten with large Allen wrench.
21. Insert previously marked Allen setscrews in nuts, and tighten. Be sure setscrews line up with hole in rotor shafts. Lock in place with center punch.
22. Cover openings in blower to prevent dirt or dust from entering blower compartment.
23. Wash face of blower thoroughly with solvent, remove any nicks or burrs.
24. See that gasket on flywheel housing is in good condition. Renew if necessary.
25. Attach hoist and place blower over studs on wheel housing. Cover top opening at once.

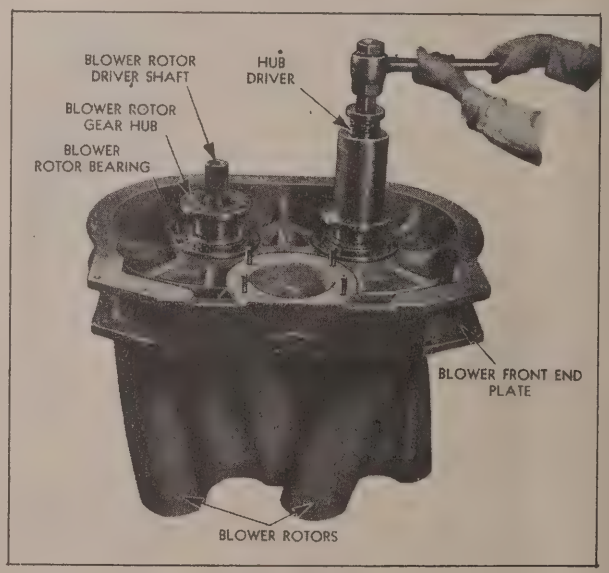


Fig. 8S
Installing Rotor Gear Hubs

26. Replace capscrews, nuts, lockwashers, and studs and tighten blower to flywheel housing. Install fuel oil strainer and filter.
27. Paint joint between blower and silencer adapter with perfect seal, and replace silencer adapter over studs on top of blower.
28. Insert all attaching capscrews, bolts and nuts, tighten the capscrew holding the silencer adapter to the blower housing on each side first and then tighten the bolt just above it, holding the adapter to the cylinder block. Break tension on first capscrews and tighten the upper bolts to force the seal out of the joint.
29. Tighten all attaching bolts evenly.
30. Replace oil feed line under blower.
31. Check blower housing gasket to flywheel housing and trim flush with bottom of blower housing.
32. Check gasket of lower blower housing for damage and replace lower blower housing. Use same tightening procedure as for tightening silencer adapter above.
33. Check relation of faces of blower housing and lower blower housing. Maximum overhang of blower housing over lower housing is .002". If overhang is more, make paper gasket and shellac on lower housing.
34. Install blower drive shaft.
35. Install accessory drive assembly. (See Section K.)
36. Install fuel oil relief valve and fuel oil piping.
37. Install intake air silencer.

Intake Silencer

Description. The air is drawn into the blower through a round intake silencer mounted on the blower intake adapter. The silencer is a double sheet metal case with screened openings at the top. Felt padding is cemented between the double layers of metal at the top and the sides of the case. A perforated metal tube is welded through the center of the case and the upper space between the outer shell and intake tube is filled with sound deadening material.

Maintenance. The only maintenance necessary on the silencer is to see that the screen is kept clean. Remove the screen to clean

Air Maze

A breather system is used to prevent contamination of the engine room atmosphere by heated, fume-laden air which would otherwise escape from the interior of the engine. This ventilation of the crankcase also reduces the formation of sludge in the oil and prevents the accumulation of combustible gases in the crankcase and oil pan.

Atmospheric air for the breather system enters the engine through the cylinder head cover breathers. The blower draws air from the crankcase through the Air Maze which prevents oil mist from being drawn into the blower.

The Air Maze element consists of a number of fine steel and copper wire screens. Oil-laden air is drawn through the Air Maze screens. The oil deposited on the wires drains to the bottom of the Air Maze housing. This separated oil is returned to the accessory drive housing through a drain tube.

Maintenance. Remove the cover plate by removing capscrews holding cover to side of case. Remove wing nut at top of element, raise element from boss and remove.

Dirt and lint should be brushed from the screen faces of the element, which should then be rinsed in hot soapy water (use water softener if necessary) and dried. It is not necessary to remove the blackened oil from the wires. Dip the element in Air Maze adhesive and replace in housing.

If excessive oil is found in the blower housing the Air Maze screen may be loose or the Air Maze drain line plugged. If the Air Maze is functioning properly the blower rotor shaft seals should be inspected and renewed if necessary.

Removing Air Maze.

1. Remove capscrews from flange at Air Maze air outlet.
2. Remove nuts from flange at intake silencer adapter and remove tube.
3. Disconnect oil drain line at Air Maze.
4. Remove nuts from lower flange of Air Maze.
5. Lift off Air Maze Assembly.
6. Disconnect oil drain line at accessory drive housing, remove clamp and drain line.
7. Disconnect Air Maze intake pipe at blower housing.

8. Remove capscrews holding pipe to bracket on accessory drive housing and remove intake pipe.

Disassembly of Air Maze.

1. Remove capscrews from front cover plate.
2. Remove cover plate.
3. Remove wingnut on top of element and remove element.

Assembly of Air Maze.

1. Reverse disassembly procedure.

Install Air Maze.

1. Reverse removal procedure.

Exhaust Elbows and Manifold

Description. The exhaust gases from each cylinder are discharged into water jacketed elbows which divert the exhaust gases to an exhaust manifold at the top of the engine. The manifold is also water jacketed.

The cooling water flows from each cylinder head into an exhaust elbow, through the jacket space in the elbow to the water space in the exhaust manifold. (See Cooling Water System, Section R.)

A thermocouple for measuring the temperature of the exhaust gases from each cylinder is located in each exhaust elbow.

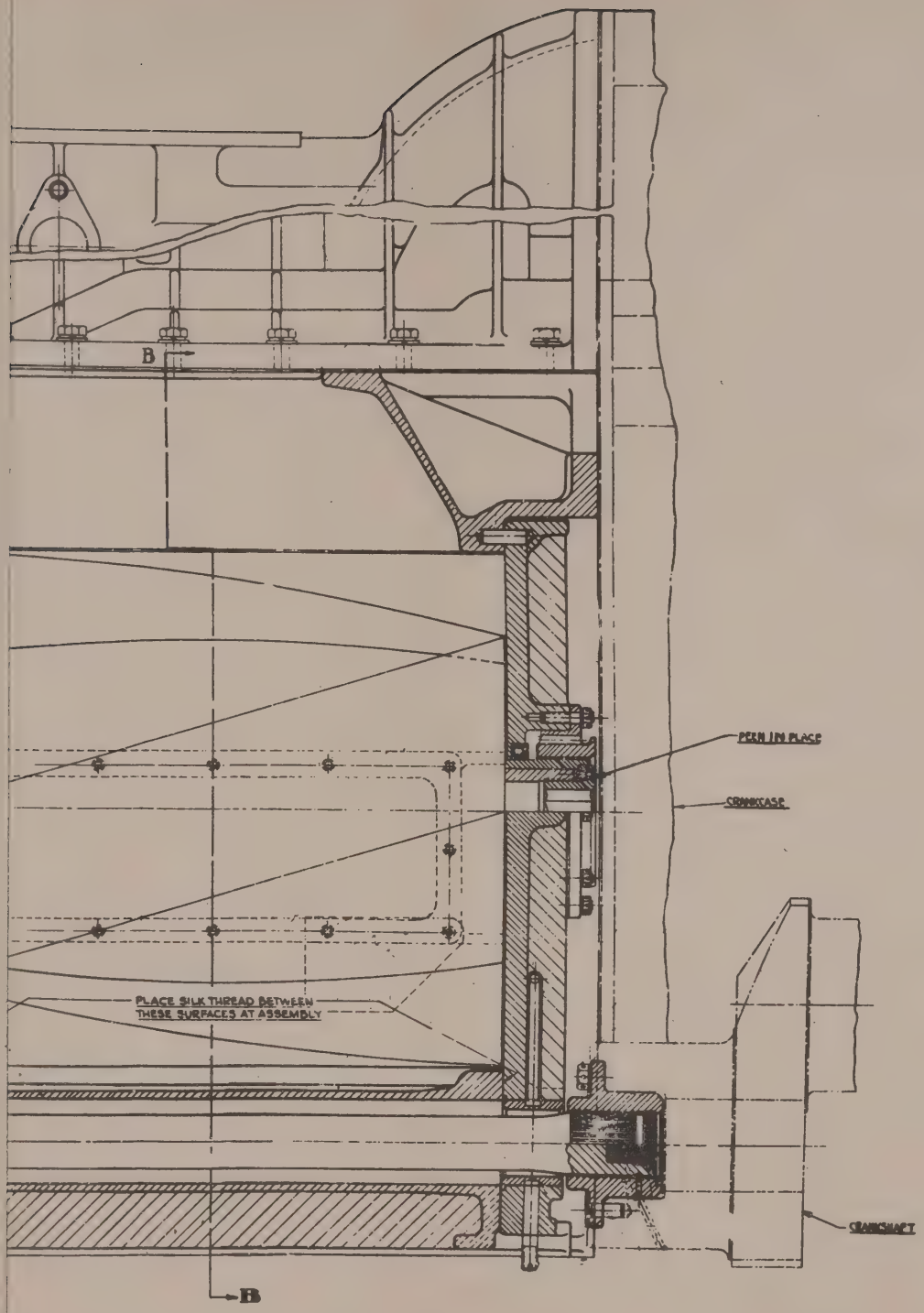
Exhaust Muffler

Two types of exhaust mufflers are used on General Motors Diesel Engines—the dry type and the wet type. Neither type of muffler contains any moving parts. Both types function as spark arresters.

The dry type muffler is equipped with a dust collecting chamber which must be emptied periodically and cleaned.

The wet type muffler requires no maintenance other than removing the drain plugs to vent the water in case the engine is to be idle for any length of time.

Inlet and outlet connections on both types of mufflers should be kept tight at all times.



ION C-C

Fig. 9S—Sheet 1
Blower Assembly

Fig. 9S
Sheet 1

8. Remove capscrews holding pipe to bracket on accessory drive housing and remove intake pipe.

Disassembly of Air Maze.

1. Remove capscrews from front cover plate.
2. Remove cover plate.
3. Remove wingnut on top of element and remove element.

Assembly of Air Maze.

1. Reverse disassembly procedure.

Install Air Maze.

1. Reverse removal procedure.

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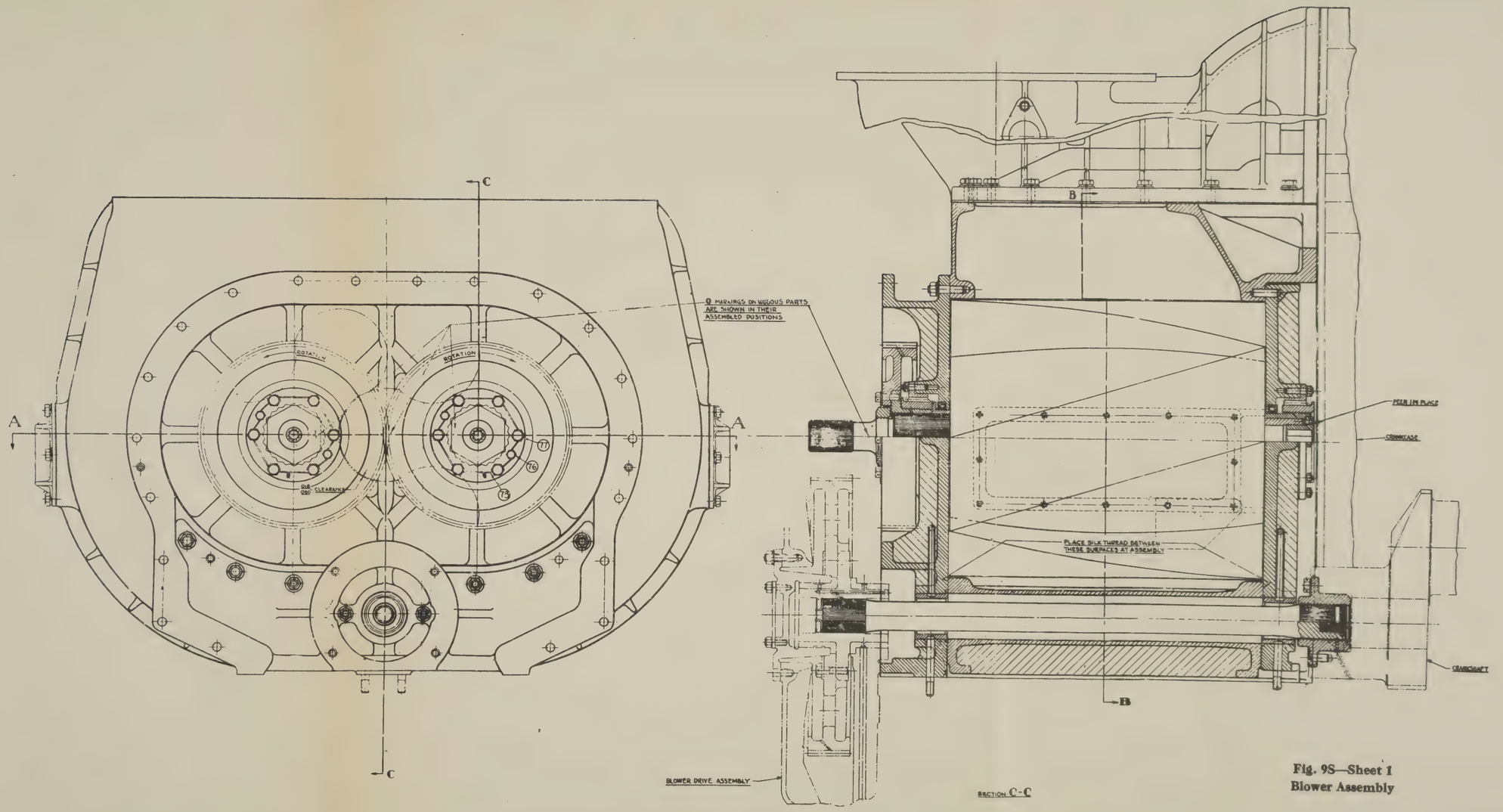


Fig. 9S—Sheet 1
Blower Assembly

Fig. 9S
Sheet 1

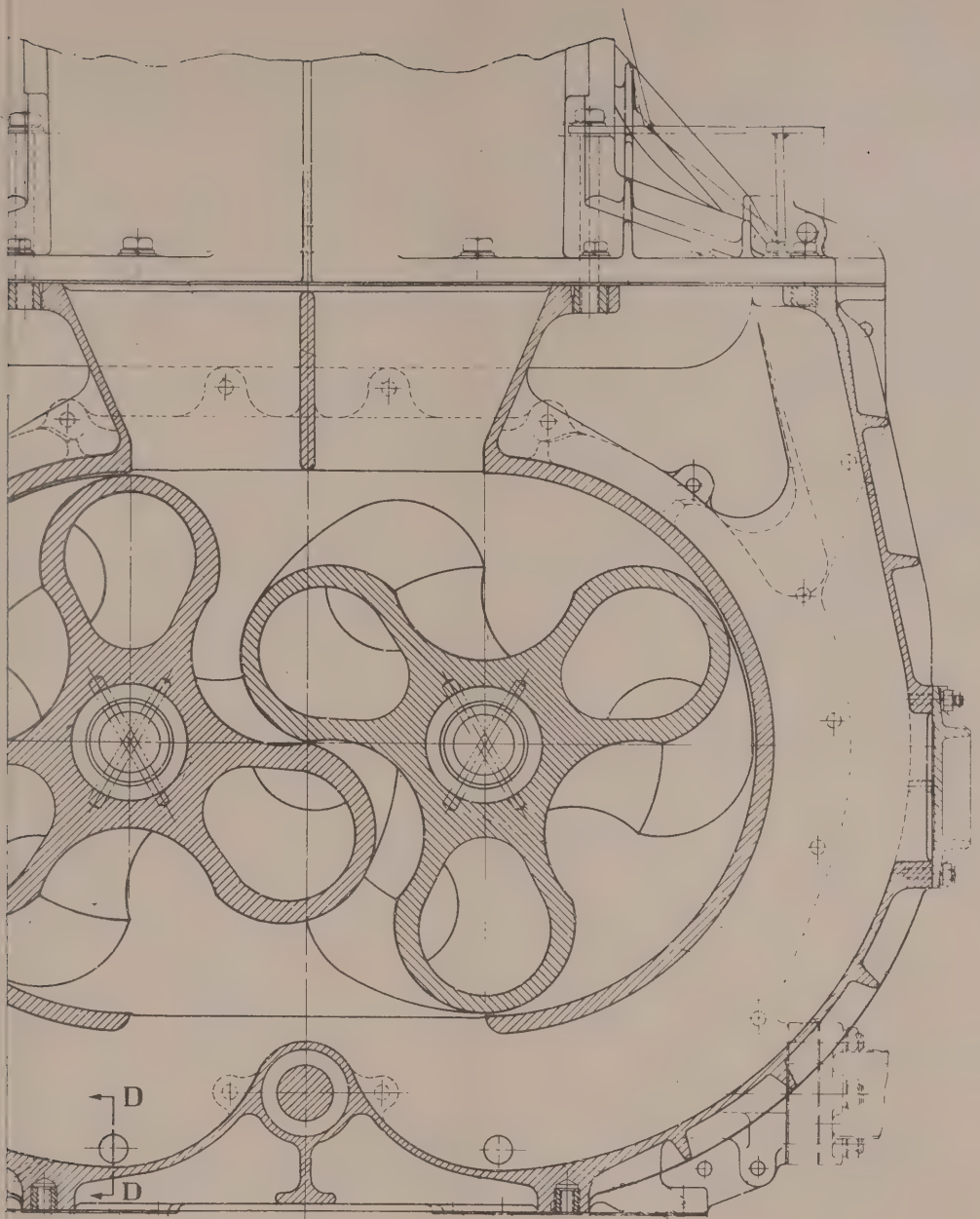
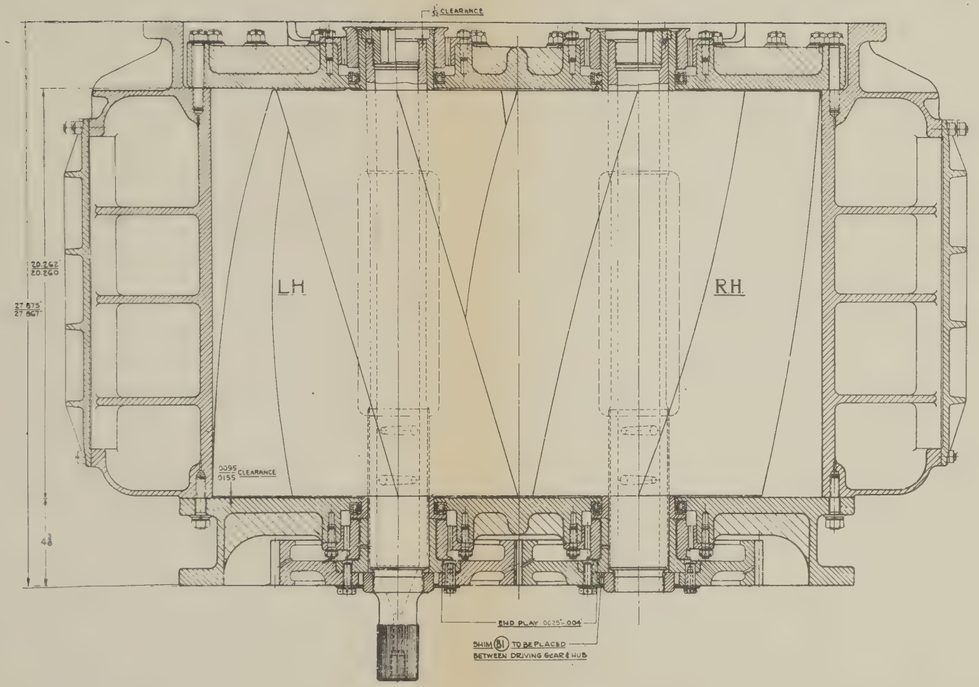
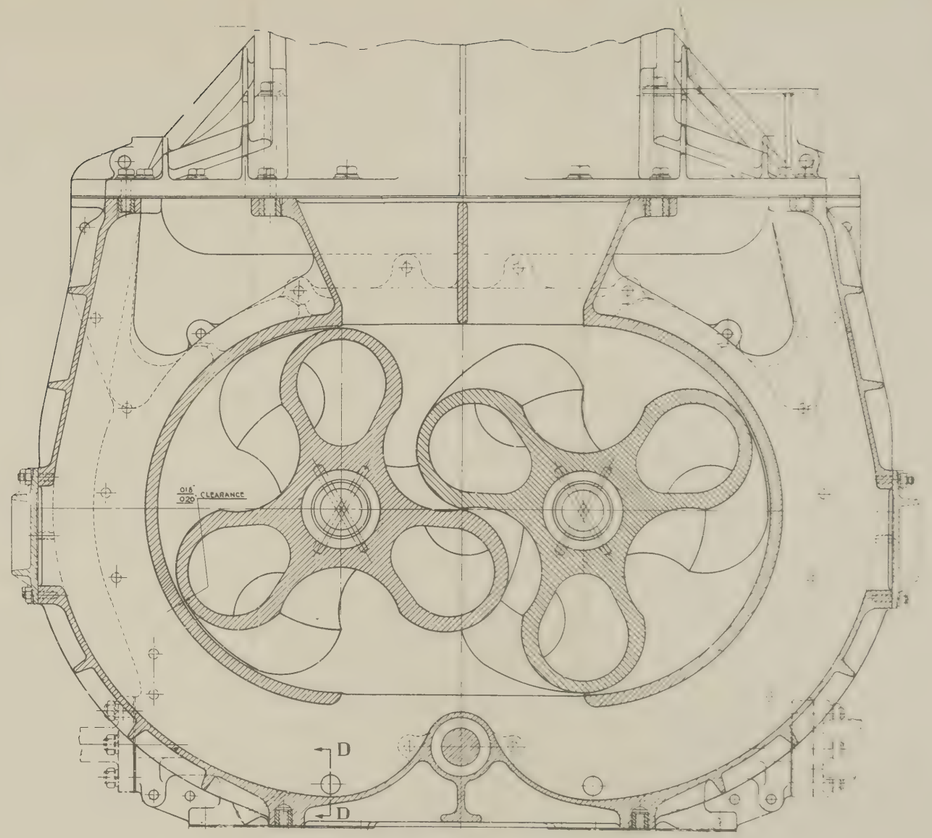


Fig. 9S—Sheet 2
Blower Assembly

Fig. 9S
Sheet 2





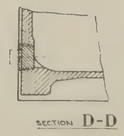


Fig. 9S—Sheet 2
Blower Assembly

Fig. 9S
Sheet 2

STARTING SYSTEM

Starting Batteries

Hydrometer Readings—Specific Gravity. The specific gravity of the electrolyte in these batteries lowers on discharge and rises again on charge.

Consequently, if we know the specific gravity or hydrometer reading, we can tell if the battery is fully charged or the amount it is discharged. The specific gravity is easily determined by allowing a hydrometer to float in the electrolyte. When the specific gravity is high or strong, the hydrometer will not sink as far into the liquid or electrolyte as when the specific gravity is low or weak.

To take a hydrometer reading, insert the nozzle of the hydrometer syringe in the electrolyte, squeeze the bulb and slowly release it, drawing up enough electrolyte to float the hydrometer freely. Holding the syringe vertically, the reading on the stem of the hydrometer at the surface of the electrolyte is the specific gravity of the electrolyte. Be sure no electrolyte drips from the hydrometer. Return the electrolyte to the same cell.

Use an accurate hydrometer.

Do not take hydrometer readings immediately after adding water. Allow a day or so for the water to mix with the electrolyte, otherwise the readings are false.

Do not use the same cell all the time to take the gravity readings. Each month change around to another cell, eventually using all cells in the battery. This recommendation is made to avoid lowering the gravity of one cell due to possible loss of a small amount of electrolyte in taking gravity readings.

Using all cells spreads the possible loss over all cells rather than having the loss taken by one cell.

Full Charge Specific Gravity. The specific gravity of the electrolyte with the cells fully charged and electrolyte level at bottom of filling tube, should be as shown below for the temperatures indicated.

Temperature	110° F.	80° F	50° F.
Electrolyte Level at Bottom of Filling Tube	1.220 to 1.240	1.230 to 1.250	1.240 to 1.260
Electrolyte Level at Splash Cover or at Top of Separators	1.265 to 1.285	1.275 to 1.295	1.285 to 1.305

From the above, it will be observed that a change of 30° F. changes the gravity reading .010 or 10 points.

The specific gravity is adjusted within the above limits at the factory and will not require adjusting during the life of the battery unless electrolyte is actually lost.

The full charge specific gravity will decrease in value as the battery ages. No definite value can be given, but this decrease is very small—not over a few points per year at the most. This change is mentioned so that it will be understood.

Discharging Rates and Capacity. The ampere hours which may be obtained from a battery are greater for a long, low rate or intermittent rate discharge than for a short high rate. This is because the voltage drops faster at the high discharge rates (amperes).

High discharge rates (amperes) should not be confused with over-discharge (too many ampere hours taken out). These batteries may be discharged, without any injury to the plates, at any rate of current they will deliver. The maximum permissible rate of discharge is limited only by the current carrying ability of the wiring, motor or other apparatus to which the battery is connected or by the current carrying ability of the cell terminals and connectors and not by the plates themselves.

Charging—Checking Adjustment. The ideal adjustment of charge would be that which will maintain the specific gravity of the electrolyte at about its maximum value without exceeding the water loss figure given in the table in the chapter entitled, "Adding Water."

Too little charge is shown by the specific gravity readings becoming lower. Too much charge is indicated by adding more water than shown in the chapter entitled, "Adding Water."

Too little charge results in a discharged battery and failure to start. Too much charge shortens battery life and increases maintenance care by having to add water more frequently.

The proper charging rate for the starting battery is automatically maintained by the "Starting Battery Charging Cabinet," see Section X. This device applies a high rate of charge, 30 to 40 amperes,

immediately after the batteries have been discharged by cranking an engine. As soon as the battery is brought close to full charge, a voltage sensitive TVR relay cuts the charging rate down to a trickle value of approximately 1 ampere. This low trickle rate maintains a constant full charge condition without the necessity of too frequent additions of water.

Adding Water. Approved water must be added regularly to each cell. The low level point is the splash cover or the top of the separators and the high level is just below the bottom of the filling tube.

The time of adding water is important in the winter time. When it is cold, add water just before the vessel goes into service in order to mix the water with the electrolyte by the charging current. If water is added and the battery left standing in freezing temperatures, the water will freeze.

In normal service it should not be necessary to add water more often than once a month. It is usually added at the time the vessel is out of service for inspection.

Nothing but water is required to be added to the batteries. Never add acid, electrolyte or any special powders, solutions, or jellies.

Electrolyte loses some of its water by charging of the battery and a little by evaporation, but sulphuric acid is never lost in this manner. Therefore, no acid or electrolyte will need to be added unless some electrolyte should be spilled or lost from the cell. Add only distilled or other approved water.

Do not add water higher than the bottom of the filling tube or electrolyte will be spread out over cell covers when the battery is on charge. Keep vent plugs tight in the cells.

All cells should take the same amount of water. If one cell takes more than the others, examine it for leakage.

Keep a written record of the amount of water added from time to time. The allowable amounts are shown below. If more than the maximum is used, unnecessary overcharging is indicated. If the minimum amount is not used for a battery in average service, undercharging is expected.

Battery Size	*Water Additions per Mo.*	
	Minimum	*Maximum*
32 Cells	7½ qts.	15 qts.

Kind of Water. The quality of water to add is distilled (not merely boiled) or other approved water. By approved water is meant that which the Electric Storage Battery Company have found safe for Exide batteries after analysing a sample.

Keeping Battery Clean. It is important to keep the battery, its connections, and surrounding parts reasonably clean and dry. Any accumulation of acid-soaked mud and dirt on top of the cells and in the compartment causes grounds, shorts, and corrosion.

Keep vent plugs tight in place at all times. The small round gas-escape hole in vent plug should be examined to see that it is not clogged with dirt. Wash all vent plugs yearly by immersing in a bucket of water and wiping clean.

Once a month blow dirt off cell covers, trays, and out of compartments with an air hose, using moderate pressure.

If tops are damp with electrolyte, or if electrolyte is spilled, it should be neutralized by applying ammonia or bicarbonate of soda solution (one pound of soda to a gallon of water). Follow with a rinsing of water.

Do not allow the solution to get into the cells. It is necessary to neutralize the continuously damp or wet spots because sulphuric acid does not evaporate and disappear as water does.

The tops of the batteries and containers should be washed with water under moderate pressure two or three times a year, but not in freezing temperatures. Increase the water pressure for washing out the battery compartment. After washing, blow the surplus water off the cell covers and out of the compartment with an air hose.

If any corrosion is experienced, scrape or brush off, and then wash with ammonia or baking soda solutions to neutralize any electrolyte remaining. After rinsing with water and drying, apply a thin coating of No-Ox-Id grease or vaseline. Lead does not corrode. Lead-plated parts on which the lead coating is worn or scraped off should be replaced or the worn area covered with a thin film of No-Ox-Id grease.

Dirty hydrometers give inaccurate readings. Therefore, the hydrometer barrel and float should be washed and cleaned at least once a month.

Check the bolted connections for tightness at least once a year. As heavy currents are required

for starting Diesel engines, it is necessary that all connections be tight and clean. A dirty or loose connection may prevent engine starting.

Records. A log book arranged for both daily and monthly records should be kept. For the daily readings, rule off pages as shown in Fig. 1T.

Date	*Pilot Hyd. Rdg.*	*Cell Readings Electrolyte Temp. °F.*	*Electrolyte Level*	*Amperes to Battery*	*Remarks*

Fig. 1T
Pilot Cell Readings

Pilot Cell Readings—Select and mark any one cell in the battery which is called the pilot cell. Take the readings of this cell for one month. Then change to another cell, eventually using each cell as a pilot.

Electrolyte Temperature—Use Exide thermometer, Cat. No. 22691, or any other accurate thermometer. The Exide thermometer shows the correction to the hydrometer reading necessary for any temperature of the electrolyte. At 110° F., 10 points would be added to the hydrometer reading. At 50° F., 10 points would be subtracted.

Record only the actual hydrometer reading. However, when using these readings for comparison from one day to the next, or from month to month, the correction for temperature should be considered.

Electrolyte Level—The watering space provided, between high and low electrolyte level, is about 1½ inches, and is sufficient for at least three months' normal operation. Indicate in this column whether it is ¼", ⅛", etc., above splash cover.

Amperes to Battery—Read the amperes to battery on the switchboard ammeter.

Remarks—Any irregularities in schedule or performance should be mentioned.

For the monthly inspection, rule the pages as shown in Fig. 2T.

Take the readings each month in the same order following through the electrical circuit. In this way the reading of each cell each month is readily compared.

If the specific gravity of any cell is over 20 points less than the other cells in the battery, the cause should be investigated and corrected. Low gravity in a cell may be due to filling too high with water, with resulting loss of electrolyte, careless hydrometer readings, or cracked jar allowing electrolyte to leak away.

Record the amount of water added each month.

Month	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Day												
Cell No.												
1.												
2.												
3.												
4. etc.												
Elec. Temp.												
Elec. Level												
Qts. Water Added												

Fig. 2T
Monthly Inspection

Records kept as suggested will be a decided aid in readily disclosing irregularities and in pointing out the way to correct them.

Important Points. Do not work on battery or in battery compartment without first opening the main battery switch.

Keep all flames away from the battery.

Do not lay any tools on top of cells.

Low electrolyte temperatures temporarily reduce the battery capacity. Restoration of normal temperatures restores the usual capacity.

Continued and frequent temperatures above 115° F. shorten the life of the battery. Provide full ventilation in warm weather.

With proper operation, the battery temperature should not be more than 10° F. higher than the temperature of the surrounding air.

By following the rules, long life will be obtained but eventually the battery will wear out. This will be evident by very low and irregular hydrometer readings which higher charge input will not improve. This condition will be accompanied by decided increases in the volume of water required.

INSTRUMENTS

Tachometer

General Description. The tachometer is of the centrifugal mechanical type and is driven from the end of the camshaft through the tachometer drive assembly, two right angle drive adapters, and a flexible shaft.

Installation. In order to assure satisfactory operation the following precautions must be observed.

1. The cable must be installed with the easiest curve possible. Loosen the right angle drive adapters locknut. Tighten the locknut when the position is found which gives the easiest cable curves. Sharp bends near the ends of the cable must be avoided, as they cause binding and rapid wear of the cable. Binding of the cable is indicated by jumping of the indicating pointer during operation.

2. The accuracy of the tachometer may be checked with a hand counter and stop watch. If a hand tachometer is used, an error of plus or minus 2 per cent may be introduced.

Maintenance. It is imperative that the following instructions and precautions be followed to insure satisfactory performance of this tachometer:

1. DO NOT use a grease gun on any part of the tachometer.

2. Ball bearings are used throughout in the tachometer and require no lubrication.

   Under no circumstances should attempts be made to lubricate the mechanism or to adjust it in any way. The greatest care must be exercised to prevent oil or grease entering the tachometer at any time.

   Should the tachometer require attention or adjustment, it should be returned intact to the factory for the necessary service.

3. The flexible shaft requires only a small amount of lubrication. Excessive lubrication is not only injurious to the shaft itself, but may cause serious damage to the tachometer mechanism. Lubrication of the flexible shaft is accomplished as follows:

   a. After each 300 hours of operation, disconnect the flexible shaft at both ends and remove the inside cable.

   b. Apply a light film of grease to the inside cable. Vaseline or any grease of about the same consistency is recommended for this purpose. Do not use any more lubricant on the inside cable than is required to coat it with a thin, even film. When too much lubricant is used, there is always danger that it will be driven into the tachometer, causing serious damage to the indicating mechanism of the tachometer.

   c. After the inside cable is coated with a thin, even film of lubricant, reinsert the inside cable in the outside covering.

   d. Reconnect the flexible shaft. See item 1 under "Installation."

4. The right angle adapters should be lubricated every 500 hours of operation as follows:

   a. Remove the adapter. Remove the 1/8 inch plug found on the side of the gear housing.

   b. Lubricate the worm gear seen inside the hole by applying a light grease to the gear while slowly turning the shaft. Only enough lubricant should be applied to wet the gear teeth as any excess lubricant will work down into the tachometer mechanism. Heavy grease must never be used to lubricate this section as it will put too heavy a load on the flexible shaft during cold weather.

   c. Reassemble the right angle drive adapters and reinstall.

Operation. When the installation has been completed, check to make sure that all parts rotate freely without binding.

The engine should then be operated to check performance of the tachometer. If installation is properly made, the tachometer pointer should give a steady indication. If the pointer has a tendency to jump, investigate immediately, checking particularly the installation of the flexible shaft to make sure that there are no sharp bends. Violent fluctuations of the pointer may also be caused by binding or excessive friction in the flexible shaft or the right angle adapters. The tendency of any part to heat up indicates excessive friction and should be investigated immediately.

If for any reason either end of the flexible shaft is disconnected, do NOT attempt to reconnect the flexible shaft while the engine is running as this places a severe strain on the tachometer mechanism and may cause serious damage.

Pyrometer

The exhaust gas temperatures are obtained with an indicating pyrometer which makes use of the thermoelectric principle. An electromotive force is generated in a circuit of two wires of dissimilar metals when the two junctions are at different temperatures. This electromotive force varies in magnitude with the difference in temperature between the two junctions. The hot junction is immersed in the exhaust gas, and the cold junction is located at a galvanometer through which the circuit is closed. This galvanometer is graduated in degrees of temperature corresponding to the voltage generated. Because the electromotive force is zero when the two junctions are at the same temperature, the galvanometer must be adjusted to indicate its own temperature when the circuit is open. The galvanometer will automatically vary its pointer position with changes in its temperature.

The pyrometer installation consists of the hot junctions or thermocouples; a pyrometer instrument, that includes a galvanometer or indicator, a rotary selector switch, and the extension lead wires, which connect the thermocouples to the instrument.

One of the two thermocouple wires is made of pure iron, and the other one is made of constantan, which is a nickel-copper alloy. The wires are twisted together and welded at the top of the thermocouple. They are mounted in a closed-end protecting tube that is made of pure nickel. The protecting tube is fitted with a terminal head, in which the connections are made between the extension lead wires and the thermocouple wires. One thermocouple is inserted in each of the exhaust elbows and the remaining one is placed in the exhaust line.

The indicator and the selector switch are mounted in a water-tight case. The switch dial is marked with numbers for the engine cylinders and it is marked with the letter C for the thermocouple in the exhaust line, which measures the temperature of the combined exhaust gases.

When the thermocouples are being connected to the instrument through the extension lead wires, the polarity from the thermocouple heads to the internal selector switch leads must be strictly observed. The extension leads are made of wires of the same materials as the thermocouple, and the extension lead with the gray tracer must be connected to the positive terminal. The extension lead wires are spliced to the selector switch leads, and the splices must be soldered and taped.

The indicator pointer is adjusted by placing the selector switch at the "OFF" position and by turning the "ADJUST POINTER" screw until the pointer is at a temperature reading on the scale that equals the temperature of the room. This setting of the pointer should be checked about once a week.

To operate the pyrometer, the knob of the selector switch is turned to the dial number that corresponds to the number of the engine cylinder that is under observation. When the instrument pointer comes to rest, the temperature of the exhaust from that cylinder is read on the scale.

The selector switch contacts and the indexing plunger should be greased with a light coat of vaseline twice a year. Each of the two switch shaft bearings should be lubricated with a drop of light machine oil.

GENERATORS, EXCITERS, AND MOTORS

MAIN GENERATOR

Each generator is coupled to the diesel engine by means of a rigid flange coupling, and has a single bearing. The armature weight is partially carried by the engine which likewise carries the end thrust. Each generator is of direct current, two wire, interpole, separately excited, open, self ventilated, drip-proof and is equipped with a series winding for electric starting of the diesel engine.

Classification and Rating

Kilowatts	605
Revolutions per minute	750
Volts	560
Amperes	1080
Degree of enclosure	Open, drip-proof
Method of cooling	Self ventilated with fan on rear of armature
Type of armature winding	Allis-Chalmers Frog Leg
Type of field winding	Shunt with a starting winding
Insulation	Class B
Excitation	Separately excited from 120 volts
Bearing	Single, anti-friction type
Duty	Continuous
Temperature rise	60° C.
Ambient air temperature	50° C.
Manufacturer's type	MC
Number of poles	6
Number of brush studs	6
Brushes per stud	7
Size of brush	2¾ x 1¼ x ¾ split

Operation. The generators may be operated continuously at any speed between 750 and 375 r.p.m., provided neither rated armature current nor normal field current is exceeded.

The switching is so arranged that either or both generators may be used to supply power to the main motors. The generator is provided with a series type starting winding for electric starting of the engine. Complete description of the operation and switching arrangement is given in the electrical control section, page X-1 to X-44, inclusive.

Construction of Generator. (See Figs. 24W-25W.) The generator has one bearing, and this is of the anti-friction, ball bearing type. The other end of the armature shaft is supported by direct connection to the engine shaft through a forged coupling.

The generator is self-ventilated by means of a fan mounted on the drive end of the armature spider. This fan blows air out radially through a vented guard, which is fastened to the rear of the yoke. After passing through the guard, the air strikes the outer drip-proof cover and is deflected so that it flows axially out of the rear of the machine. The air is drawn into the machine at the commutator end.

The armature spider and the shaft are milled from a solid steel forging. The armature core is made up of low-loss steel punchings which have been shrunk onto the spider in such a way that a groove, semicircular in cross-section, punched in the core lamination matches a similar groove in the face of the radial spider arm. The hole so produced is reamed and a long stud inserted. The end heads are added and with the nuts drawn up tight the armature core is solidly keyed to every arm of the spider.

Commutator. The commutator has a diameter of 16 inches and a 9½ inch face. It is of the conventional "V" ring construction, mica insulated

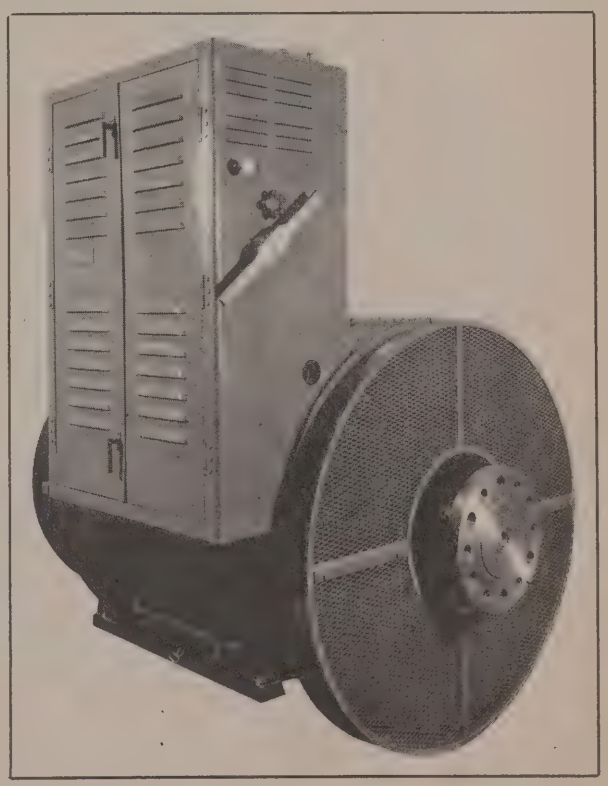


Fig. 1W
Main Generator - Coupling End

throughout. The commutator segments are hard-drawn copper. The insulation of the segment and "V" ring is mica plate with shellac binder. The segments are held in place by front and rear "V" rings. The front "V" ring is adjustable and the commutator may be tightened by the tap bolts located at the front of the commutator. The commutator has been seasoned at the factory and no additional adjustments should be necessary.

Brush Rigging. The brush yoke is made of plate steel. Brush brackets are bolted to the brush yoke

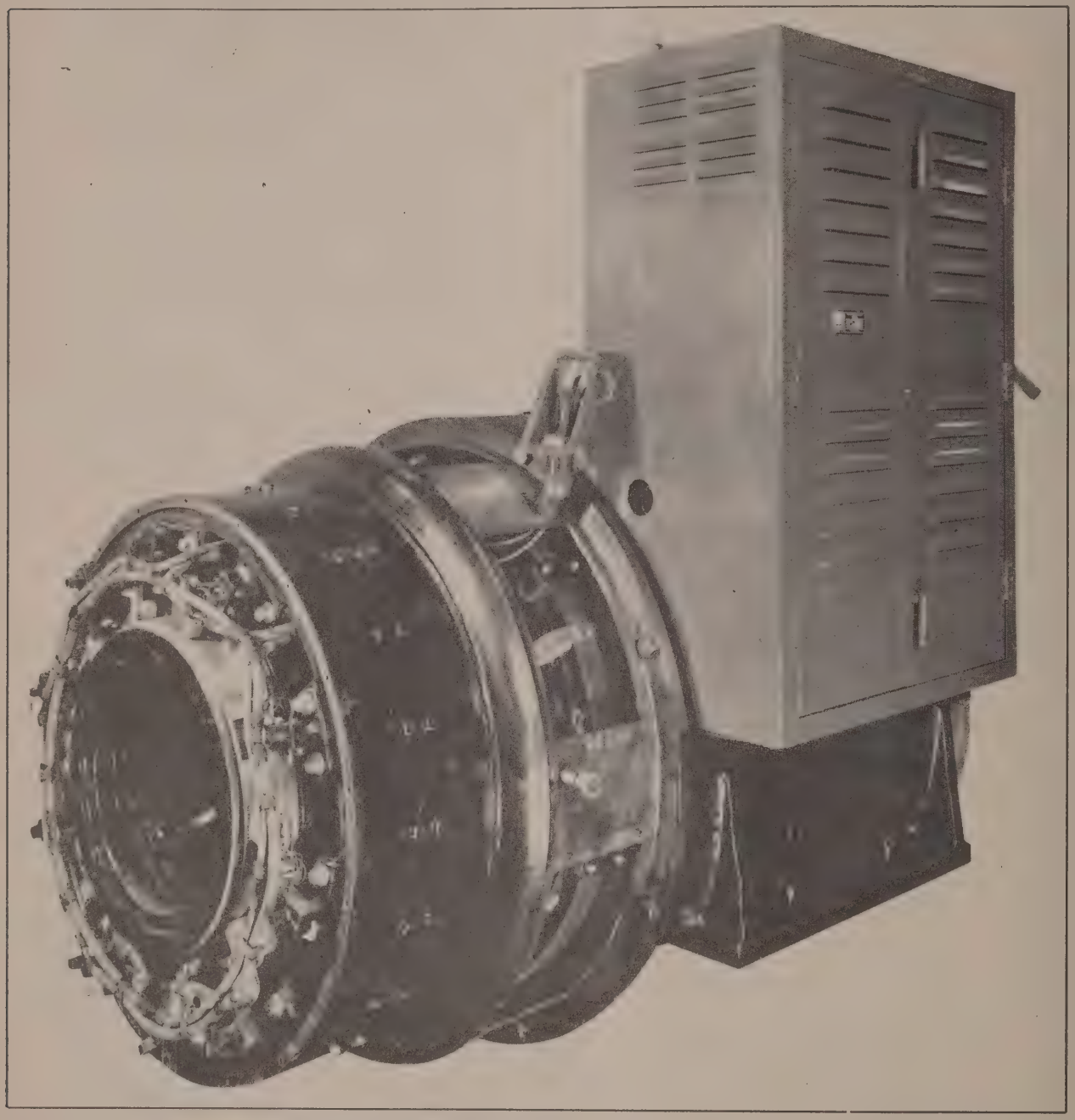


Fig. 2W
Commutator End - Partially Assembled Generator

by means of two bolts. Brackets may be adjusted to compensate for commutator wear. The brush-holders are made of cast brass and are mounted on the spline way, which is on the brush brackets, for axial adjustment. The brush-holders are bolted to the brackets and staggered in such a way that the complete wearing surface is covered by both positive and negative brushes. The brush rigging may be shifted by loosening the set screws (36) holding the rigging in place. One of the set screws acts as a dowel to hold the brushes in the correct running position. However, if the brush rigging has to be shifted to return it to the correct running position, as might be the case in reassembling the generator, use the holes in the brush yoke provided for this purpose. These holes are made accessible by a slot in the yoke. *Do not move brush rigging by prying against brush brackets.*

Field Poles. The main field poles are of high permeability steel punchings securely riveted together and bolted to the field yoke. Shims are provided behind the poles for air gap adjustment. The interpoles, or commutating poles, are machined out of high permeability steel bar stock. They are securely bolted to the yoke and shims are provided for air gap adjustment.

In case either the main poles or interpoles are removed, care should be taken to put them back in the exact original positions with the original shims in place.

Yoke. The field yoke is made in one piece of high permeability rolled steel. After welding, the yoke is carefully annealed to remove all stresses and the generator feet are welded to the lower half of the yoke.

Fan. The armature fan is fabricated of sheet steel and is bolted to the rear armature end head. It is of split construction for ease in assembling.

Main Field Coils.

Shunt Coil

Number of turns	386
Bare size of wire	.1442 inches square
Insulated size of wire (asbestos covered)	.1633 inches square
Developed length per coil	1816 feet
Resistance per coil at 25° C.	.751 ohm
Weight of copper per pole	140 pounds

Series Coil

Number of turns	2
Bare size of wire	.578″ x 1.16″

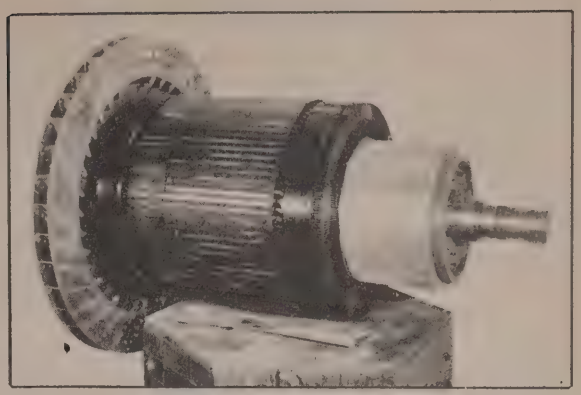


Fig. 3W
View of Commutator End of Armature

Resistance per coil at 25° C.	.000144 ohm
Weight of copper per pole	26 pounds
Main pole air gap	.239 inch

As coils are being wound, each layer is painted with a heavy coat of bakelite cement. After coils are insulated, they are baked for four hours at 150-170° F. and then baked for 18 hours at 240-270° F. After coils have cooled, they are dipped in air-drying varnish.

Commutating (Interpole) Coil

Number of turns	9
Size of copper conductor	1.125″ x .6″
Conductor built up of	9 (.125″ x .6″)
Developed length of conductor	36.25 feet
Resistance per coil at 25° C.	.00437 ohm
Copper weight per coil	94 pounds
Interpole air gap	.498 inch

(Coils are connected in two parallel circuits.)

Armature Winding. The armature coils are held in place by the bakelite slot sticks and the non-magnetic steel band wire on the end connections. The only soldered joints in the armature are at the commutator necks which are easily accessible. *These must be soldered with pure tin because of the high operating temperature of the machine.*

Armature Data

Number of slots	87
Conductors per slot	12
Turns per coil	1
Size of copper conductor	.80″ x .35″
Total weight conductor copper	368 pounds
Resistance at 25° C.	.00611 ohm
Length of copper per coil	73 inches

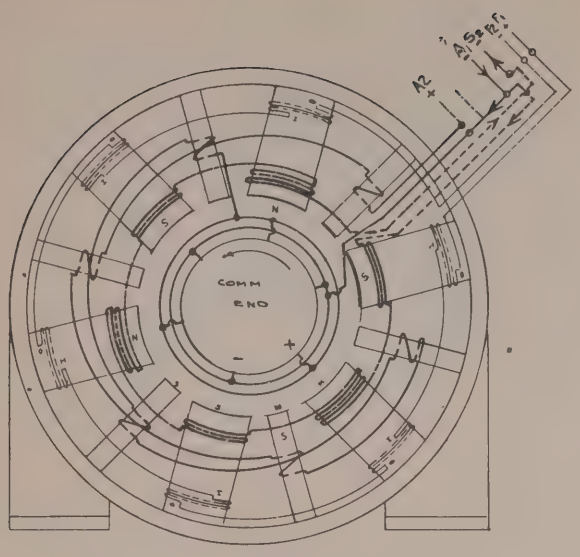


Fig. 4W
Generator Connection Diagram

Varnish Treatment

a. After the field structure is completed, with coils assembled, the whole structure is baked in a hot air oven for 10 hours at 220-240° F.

b. The field structure is then removed from the oven and cooled to approximately 125° F. It is then dipped in varnish and allowed to soak until all air bubbles stop rising.

c. The field structure is then removed from the dipping tank and all excessive varnish is drained off after which it is baked for 10 hours at 220-240° F.

d. Steps (b) and (c) are repeated once.

Note: Baking time does not include time required to bring structure up to specified temperature.

The varnish treatment for the armature is the same as for the field structure.

EXCITER

The exciter is the overhung type. The exciter yoke is bolted to the generator housing by means of substantial stud bolts. See Fig. 26W. The armature spider is pressed on the generator shaft and is held in place radially by means of a key and axially by means of two tap bolts.

Classification

Degree of enclosure.....Drip-proof, fully protected
Method of cooling.....Ventilated by generator fan
Type of armature winding.....Series
Type of field winding.....Shunt
Insulation.....Class B
Excitation.....Self-excited
Bearing.....
Armature spider is pressed on generator shaft
Temperature rise.....60° C.
Ambient air temperature.....50° C.
Type.....Overhung
Number of poles.....10
Number of brush studs.....10
Brushes per stud.....1
Size of brush.....$2\frac{3}{4}$" x $1\frac{1}{4}$" x $\frac{5}{8}$" split

Rating

Kilowatts.....24
Revolutions per minute.....375/750
Volts.....120
Amperes.....200

Operation. The exciter may be operated at rated voltage at any speed between 750 and 375 r.p.m., provided rated armature current and normal field current are not exceeded.

Construction of Exciter. (See Fig. 26W.) The exciter yoke is bolted to the generator front housing as described in the first part of the exciter description. The same materials are used in the exciter as in the generator.

The punchings are held against the rear end head by means of a key. The rear end head is cast as part of the spider.

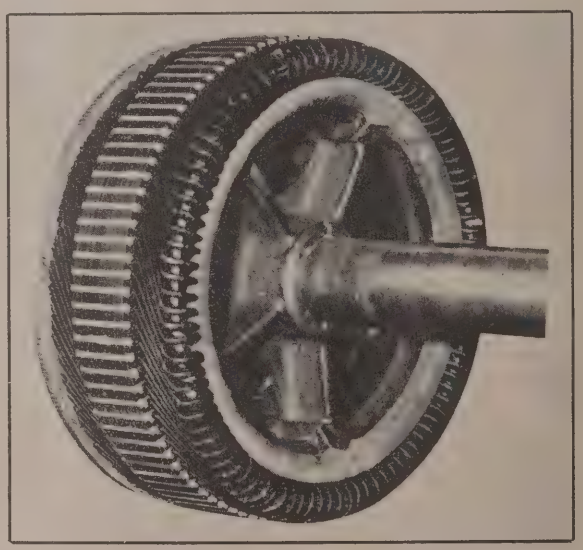


Fig. 5W
Exciter Armature

The commutator has a diameter of 21 inches and a $1\frac{13}{16}$ inch face. The construction is similar to that of the commutator on the generator.

Brush Rigging. The brush yoke is made of plate steel. Brush brackets are bolted to the brush yoke by means of two substantial bolts. The brush rigging is held in place by set screw (See item 23, Fig. 26W). These must be loosened before the brush rigging can be shifted. The brackets may be adjusted to take care of commutator wear by loosening the two bolts holding the brackets on the yoke. (See item 19, Fig. 26W.)

Main Field Coils

Shunt Coil

Number of turns	420
Bare size of wire	.0808″ diameter
Insulated size of wire (double glass covered)	.0908″ diameter
Developed length	578 foot
Resistance per coil at 25° C.	.886 ohm
Weight of copper per pole	11.4 pounds
Main pole air gap	.0919 inch

Commutating (Interpole) Coil

Number of turns	18
Bare size of copper conductor	.80″ x .18″
Conductor built up of	.80″ x .18″
Developed length of conductor	18 feet
Resistance per coil at 25° C.	.0010980 ohm
Weight of copper per pole	9.75 pounds
Interpole air gap	.109 inch

Armature Data

Number of slots	98
Coils per slot	3
Turns per coil	1
Size of copper conductor	.045″ x .70″
Total weight of conductor copper	91 pounds
Resistance at 25° C.	.0439 ohm
Length of copper per coil	28.5 inches

The varnish process is the same for the exciter as for the generator.

Weights of Generator and Exciter

Exciter armature	540 pounds
Generator armature	3,190 pounds

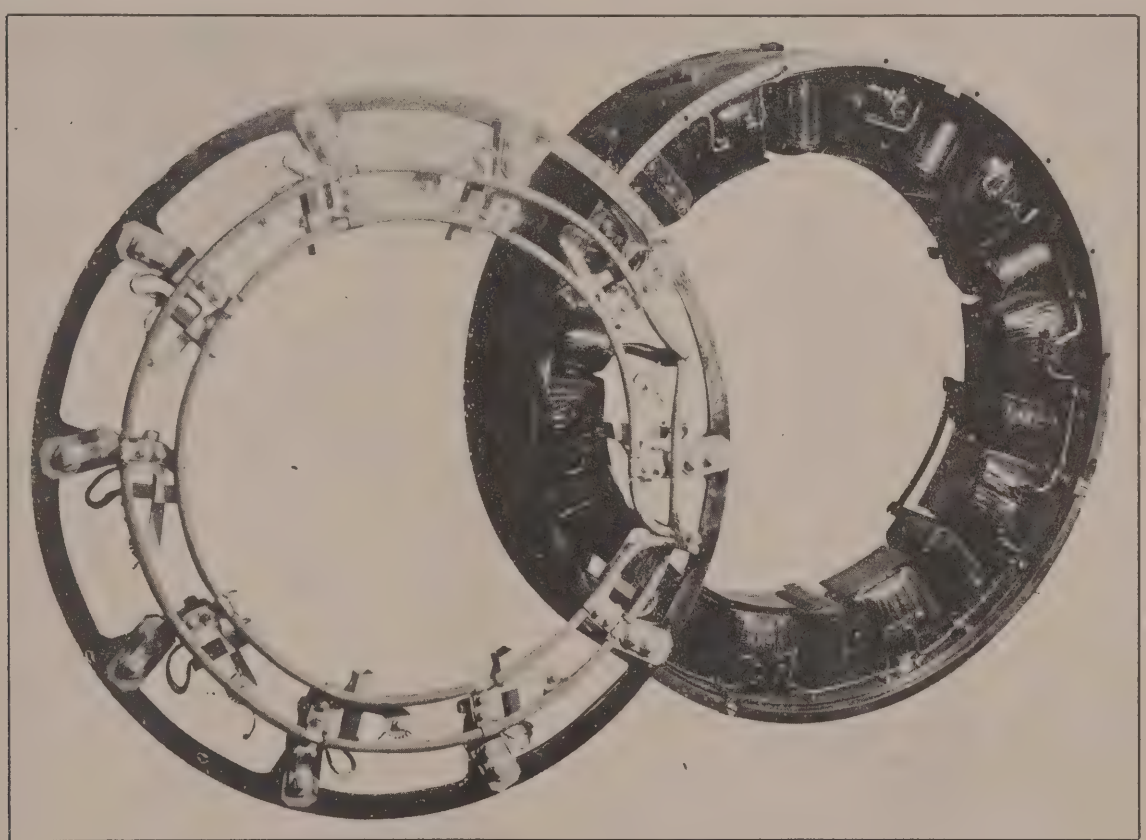


Fig. 6W
Exciter Field and Brush Yoke Assemblies

Switch box	380 pounds
Exciter field	760 pounds
Total weight of unit	13,500 pounds

Bearing Lubrication. The machines are shipped from the factory with the bearings packed with grease and ready for operation. Grease should be added to the bearings after four months of continuous operation and the bearings should be cleaned and packed with new grease once a year. The bearing housing should be one-third to one-half full of grease. An excessive quantity of lubricant will cause the bearing to run hot and may cause grease to get into the machine and on the commutator and windings.

One grease cup full of grease should be added after the fourth month of service. After forcing the grease into the housing back off the grease cup so that excess grease may be forced out by the pressure built up in the housing when the machine is running. Examine the inner bearing shell to see if grease is backing out between the shaft and the bearing shell.

Once a year the bearing should be cleaned and packed with new grease. Remove exciter as described under "Exciter Removal." Remove bearing housing as described under "Bearing Removal," except leave bearing on shaft.

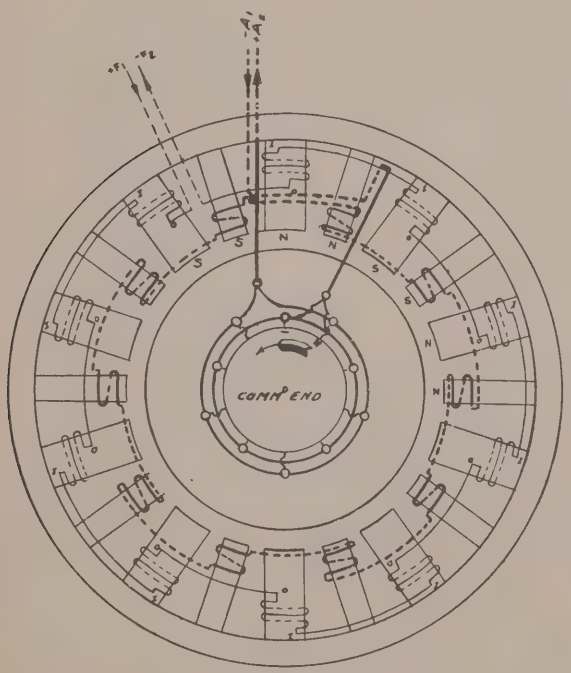


Fig. 7W
Exciter Connection Diagram

Wash bearing and bearing shells with carbon tetrachloride or other solvent. Rotate bearing by hand when cleaning. The use of high pressure air is not recommended. Flush bearing with lubricating oil and wipe dry with clean cloth. Pack new grease between bearing balls. Pack enough grease into bearing shells to fill enclosure one-third to one-half full of grease.

Excessive pounding or bumping on shaft, coupling, or bearing parts should be avoided as this may result in injury to the bearing.

Exciter Removal.

1. Remove exciter end cover. Lift exciter brushes from the brush-holders. Take off covers over openings in bearing housing. Place hitch on eye bolts in exciter yoke, remove nuts from studs which secure exciter yoke to bearing housing, and take off exciter yoke.
2. Place sling around exciter armature core. Remove the two $\frac{3}{8}$" cap screws which fasten exciter armature hub to generator shaft. Jack exciter armature off generator shaft by turning a $1\frac{1}{4}$" bolt into the threaded hole in the center of the spider hub.

Bearing Removal

1. Remove exciter as described under "Exciter Removal."
2. Block armature in position by placing fiber sheets in the air gap under the armature. Remove coupling end housing and loosen coupling bolts.
3. Back out cap screws which fasten bearing shells to bearing housing one half inch and tap on these with a hammer to force inner shell out of housing. The outer shell may be loosened with a screw driver or chisel. Then remove the screws and the outer shell and push the inner shell away from the housing. Attach a sling to the bearing housing, take out housing bolts, and remove housing.
4. Pry lockwasher tabs out of notches in bearing locknut and remove locknut and lockwasher. A pulling device is required for removing the bearing from the shaft if the bearing is to be removed without damage. Pressure for removing the bearing should be applied to the inner race only.
5. When assembling a bearing on the shaft the bearing should be heated in oil to about 100° C.,

slipped on the shaft, and tightened securely against the shaft shoulder with the locknut.

6. When replacing outer shell be careful that cup leather seal is not damaged.

Axial Location of Ball Bearing. The bearing outer race is located between the shoulders of the bearing shells which extend into the housing bore. The space between the bearing shells is one-eighth inch larger than the width of the bearing race. This clearance is provided to permit slight axial adjustment and expansion of the shaft without subjecting the bearing to axial loading. An excessive thrust load leading to fatigue failure of the bearing may result if the bearing race is forced against a bearing shell by tightening the coupling bolts or by expansion of the shaft.

The shafts should be coupled with the bearing equally spaced between the bearing shells. This position can be determined before coupling the shafts by moving the armature as far as it will go in either direction with the armature resting on fiber sheets placed in the air gap, or supported by a sling. The end positions can then be located and the mid-point determined by suitable measurement or reference mark which can be checked after coupling the shafts. The armature should be moved by using a bar on the coupling flange. Pounding or bumping on the shaft may damage the bearing.

Armature Removal

1. Remove exciter as described under "Exciter Removal."
2. Remove bearing housing as described under "Bearing Removal," but leave bearing on the shaft.
3. Remove coupling bolts. Unbolt fan from armature end head and rest fan on engine side of coupling.
4. Lift brushes from brush-holders. Disconnect the two flexible connectors from the brush rigging connecting rings. Release set screws which hold the brush yoke and remove the complete brush rigging.
5. With a sling around both ends of the shaft move the armature through the yoke as far as the sling at the coupling end will permit. With a sling around the bearing end of the shaft and raising the coupling end with a bar of wood move the armature through the yoke until a sling may be placed around the armature core. Keep padding between the under side of the armature and the pole pieces. Do not lift on the commutator.

Alignment of Generator. Engage the male and female fit of the coupling halves and insert coupling bolts. Leave space between coupling halves for the insertion of feeler gauges. Locate the bearing end of the yoke so that the coupling faces are parallel. Locate the coupling end of the yoke so that the air gap is uniform. Tighten the coupling bolts and then locate the yoke axially so that the bearing is in the mid-position of its axial clearance in the bearing housing.

MAIN MOTORS

Each motor is arranged for coupling to the main propulsion gear. The motors have one bearing and are direct current, two wire, interpole, separately excited, open, self ventilated, drip-proof type.

Classification and Rating

Horsepower	765
Revolutions per minute	700/875
Volts	560
Amperes	1080
Degree of enclosure	Drip-proof
Method of cooling	Self Ventilated with fan on rear of armature
Type of armature winding, Allis-Chalmers Frog Leg	
Type of field winding	Shunt
Insulation	Class B
Excitation	Separately excited from 120 volts
Bearing	Single anti-friction type
Temperature rise	60° C.
Ambient air temperature	50° C.
Manufacturer's type	MC
Number of poles	6
Number of brush studs	6
Brushes per stud	6
Size of brush	2¾" x 1¼" x ¾" split

Operation. The motors may be operated at any speed between 700 and 875 r.p.m. provided rated armature current and normal full-load field current are not exceeded.

Construction of Motor. (See Figs. 25W and 27W). The construction and electrical properties for the motors and generators are the same except that the motors have a different shunt field winding and have no series field winding.

Main Field Coils

Shunt Coil

Number of turns	350
Bare size of wire	.1620 inch square

Insulated size of wire (Asbestos covered)..... .1810 inch square
Developed length per coil.....1620 feet
Resistance per coil at 25° C..... .535 ohm
Weight of copper per pole..... .....150 pounds
Main pole air gap..... .367"

The varnish process is the same for the motor as for the generator.

Bearing Lubrication. The instructions for generator bearing lubrication, page W-6, apply to the motor bearings except it is necessary to remove the outer bearing shell to inspect and add grease to the bearing. Also, there is no exciter on the motor.

Bearing Removal. See instructions for bearing removal for generator, page W-6, and omit reference to exciter.

Armature Removal. See instructions for armature removal for generator, page W-7 and omit reference to exciter.

Alignment of Motor. The instructions for the alignment of the motor are the same as for the generator. (See page W-7.)

CARE AND OPERATION

The interior and exciter of the machines should be kept clean. Dirt and oil must not be allowed to accummulate either inside or outside of the machines.

It is necessary that surface inspection of the machines be made daily. Whenever insulation resistance drops to one-half megohm, it is recommended that a complete check be made of the machine. All parts should be wiped down with a clean rag, cheesecloth being preferred for the windings. A material that might deposit lint should never be used. Compressed air may be used for cleaning inaccessible parts, but its use is not recommended, inasmuch as it has a tendency to drive dirt between the coils rather than out of the machine. A vacuum cleaner with a small inlet is far more effective in cleaning between the coils.

If insulation resistance is still low, the windings should be cleaned with carbon tetrachloride. (See also Main Poles and Coils.) The commutator heads and creepage surfaces should also be thoroughly

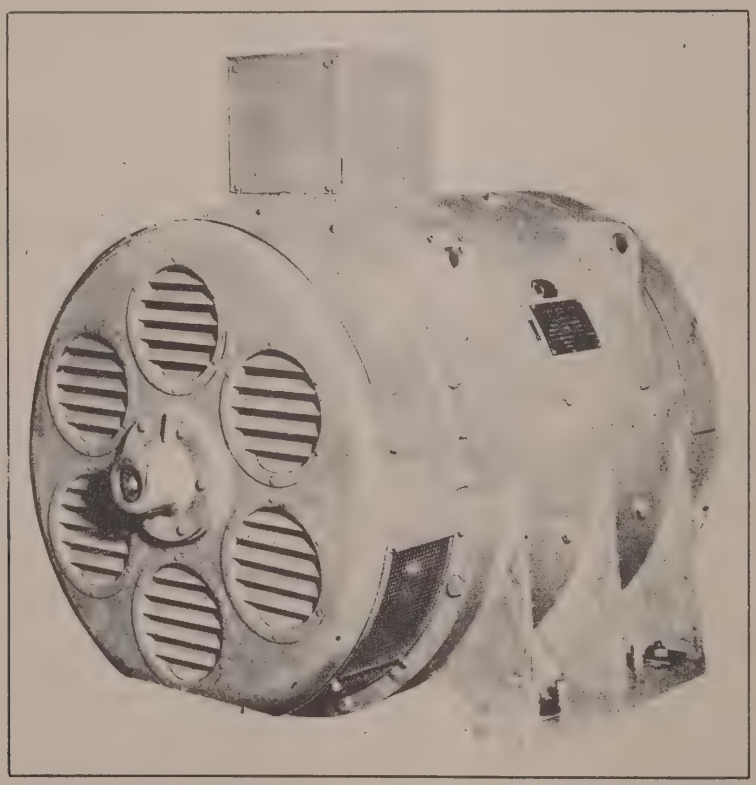


Fig. 8W
Main Motor

cleaned. For drying windings, it is recommended that the complete machine be covered with canvas and that lamps or heating units be used. These should be distributed so that the temperature of all parts will be uniform. If insulation resistance is not too low, reduced current may be passed through the shunt field coils to accomplish the same purpose. However, this should never be done when field coils are wet or actually grounded, for short circuits may develop in the coils. In using this method, care should be taken so that there will be no high voltage to ground. It should be remembered that reduced voltage across the terminals of field coils is no assurance of low voltage to ground. When drying coils with power applied, have several thermometers on the coils. Take readings every fifteen minutes for a few hours and watch closely for short circuited coils. It is desirable to record the voltage drop of individual coils at one-half hour intervals. Do not continue drying after insulation resistance becomes constant.

When dry, coat the windings and adjacent parts with high grade air drying varnish. Do not use lead or zinc paints inside the machines. Never apply varnish alone to increase the insulation resistance. Clean all parts and repair any defects first, then apply the varnish. All studs, nuts, and bolts should be inspected regularly and should be kept tight.

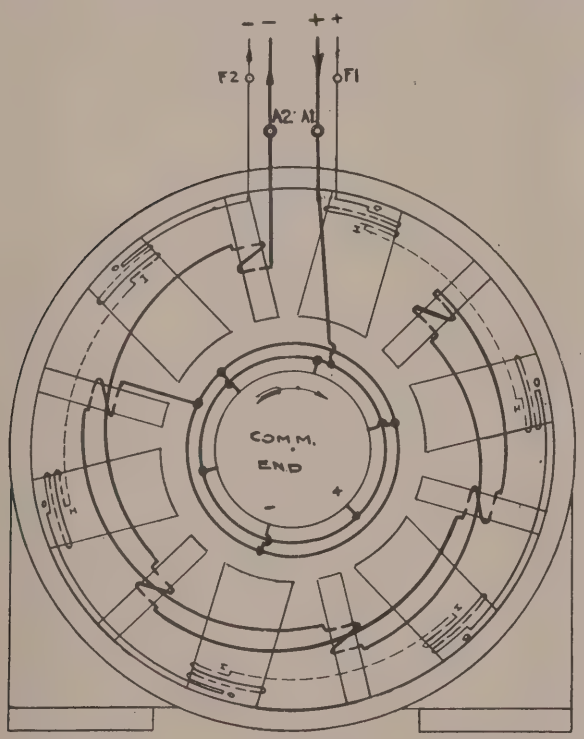


Fig. 9W
Motor Connection Diagram

In case of fire shut down machines immediately. Use carbon tetrachloride but not soda and acid extinguishers. If it is possible to get near the machines, cover with canvas and turn on smothering steam.

Armatures. It is important that air space between coils be open for free circulation of air. This is also true of the openings between the shaft and core plates. Do not allow dirt or other foreign material to accumulate on the armature, particularly in locations where it will restrict the free circulation of air. It is of major importance that no oil or dirt accumulate above the commutators for the large creepage distances provided between the commutator bars and the heads would have seriously reduced protective values. Keep this portion dry and occasionally coat with special insulating compound manufactured for this purpose.

Armature coils should be cleaned regularly and should occasionally be thoroughly dried and varnished in accordance with the preceding instructions.

Steel banding wire should be checked regularly and replaced if any bands show signs of defects, or if soldered clips show signs of failing.

Commutators. Successful operation and long life of the machines depends largely on the fact that the commutators are kept clean and free from oil or dirt. Wipe the heads and ends of the "V" rings frequently to keep them in good condition. Use special insulation compound for these parts

The commutator should be wiped occasionally with a piece of dry canvas. Waste, or soft material should not be used for this purpose. Oil, vaseline, or so-called commutator compounds should never be used on the commutators.

Also keep undercut between copper segments clean. This will prevent burning between bars and possible short circuit of armature coils.

Do not continually sandpaper and stone the commutators.

Never use emery cloth. If sanding or stoning should be necessary, make sure that the paper or stone fits the surface of the commutator.

After the machines have run for a short period,

the commutators will usually have a dull brown finish. This is the proper surface. Do not try to keep the commutators bright and shiny. If mica between commutator segments becomes higher than the copper, the slots should be cleaned. This is easily done with a hacksaw blade which has the "set" ground off. Good judgment should dictate this treatment for continual cleaning of the undercut with a sharp instrument will wear down the mica to such a point that an excess amount of carbon dust may collect in the undercut. After the mica has been cut down with saw blade, file or other instrument, it is desirable to sand the commutator lightly to remove any burrs on the edges of the copper segments.

If commutators have high bars or are rough, they should be turned, otherwise the condition may cause excessive sparking and heating of the commutators. Other results would be severe burning of the bars and possible loosening of the armature leads.

When turning commutator, canvas should be fitted around the armature so that copper dust will not enter the spaces between the windings. If practical, a vacuum cleaner should be placed in such a position that the flying dust will be collected. When finished, the machine should be thoroughly cleaned, but do not use compressed air, for it will blow the copper dust through the entire machine.

Successful operation of the machines depends largely on the proper functioning of the commutators.

Main Poles and Coils. Main poles are held to the magnet frames by bolts which may be removed with standard wrenches.

Dirt must not be allowed to collect between the coils and the magnet frames. If dirt cannot be readily removed, release the holding bolts and wipe the coils and frames dry with a cloth. Dry the coils, coat with air drying insulating varnish and tighten bolts. Be sure that the bolts are thoroughly tightened, and that there is no misalignment of the poles.

If a coil should become damaged, remove the coil and pole piece from the machine. This can be done without removing the armature. When removing the coil from the pole, or when reassembling, do not damage the sheets of insulation which are wrapped around the pole.

Should it be necessary to replace any of the taping, dry the coil thoroughly and coat with air drying insulating varnish before retaping. Never apply varnish to a damp coil, for it will tend to seal the moisture and may cause trouble.

When removing a coil, be sure to check the air gap before releasing the holding bolts. Then disconnect the cross connectors and check the markings to make sure the connectors will be replaced in their proper positions. When bolts have been released, observe the number and thickness of the shims. Care should be taken in withdrawing or replacing a coil so that the pole will not damage the armature. The use of a sheet of pressboard rubbed with paraffine and inserted in the air gap will often make this operation easier.

Commutating Poles and Coils. Commutating poles are held in the same manner as the main poles, and the method for removing and replacing an interpole coil is similar to that for a main field coil.

Voltage drop across any one interpole coil will be very low, so there is ltte or no chance of short circuited turns. However, the voltage to ground may be practically as high as the line voltage. Because the interpole coils are of bare copper and have no taping it is important that no dirt collect on the insulating plates or lodge between the plates and magnet frames. If it is impossible to readily remove the dirt between the plates and the frames, the poles may be released in the same manner as the main poles.

The method of removing an interpole coil is similar to that for a main field coil.

Brushes and Rigging. The brush rigging is of rigid construction in order to eliminate vibration. All studs must be kept tight. Clean insulator plates regularly. Never run the machines unless the brush rings are locked in their proper positions.

Brush brackets should be kept in their original position so that they are square with the commutator segments and that the distances between the brushes around the commutator are equal. Brushholders fit in grooves in order to assure proper alignment, and are removable.

The brushes which are furnished for this application are of a type and grade selected to give best operating characterstics. This type and grade should not be changed without consulting the manufacturer of the equipment. Brushes should not be loose in the holders, neither should they be so

tight that they do not move freely. There should be a clearance of .005" to .014" between the brush and holder measured in line with the shaft. The clearance in the other direction (perpendicular to commutator bar) between the brush and holder should be .025" to .005". New brushes should be sanded to fit the surface of the commutator. (Do not allow the carbon dust to be blown through the machine.) Spring tension on the brushes should be approximately two and one-half pounds per square inch of brush surface.

SAMPLE CALCULATIONS

Generator Input. Illustrating by example the method of determining main generator kilowatt input, based on known output readings, assume for this example, that from the meter readings taken from the circuit instruments, the following data are obtained:

Terminal volts	560
Armature amps	1080
Generator speed	750
Generator field amps	23.9

The output is thus, volts × amps = 605 kw.

Having the output, then the input is obtained by adding the losses, which are determined as follows:

a. Windage plus bearing and brush friction, read directly from Fig. 10W at 750 r.p.m. ..... 3.80 kw.

b. Core loss is determined by uses of curves, Figs. 11W and 12W, as follows: First add to terminal voltage as read (560 volts) the volts drop as read from Fig. 11W at 1080 amps. hence
$E = 560 + 13 = 573$
Using 573.0 volts, core loss may be read directly from Fig. 12W at 750 r.p.m. thus ..... 2.75 kw.
(Interpolation may be required for such readings of generator speed as not shown by the curves on Fig. 12W.)

c. I^2R (copper) loss and brush loss are read directly from the upper curve on Fig. 13W at 1080 amps. thus ..... 14.00 kw.

d. Stray load loss is taken at 1% of the output, thus 1% of 605 kw. ..... 6.05 kw.

Summarizing the foregoing losses:

a. Windage plus bearing and brush friction	3.80 kw.
b. Core loss	2.75 kw.
c. I^2R and brush loss	14.00 kw.
d. Load loss	6.05 kw.
Total	26.60 kw.

Kw. Input = 605 + 26.60 = 631.60 kw.
Eff. (without shunt field loss) =

$$\frac{\text{output}}{\text{input}} = \frac{605}{631.60} = 95.79\%$$

Generator Efficiency. True main generator efficiency (as determined by the separate loss method) is expressed by the relation

$$\text{Eff.} = \frac{\text{output}}{\text{output} + \text{losses}}$$

It will be noted from the foregoing computation that neither the shunt field input nor loss was included, since this loss is not chargeable to the output. It is, instead, furnished as excitation loss directly from the excitation circuit, i.e., the overhung exciter. For purposes of expressing efficiency of the generator in true meaning of overall efficiency, field input and loss is also included, and should be read directly from the curve on Fig. 14W at 26 amps. ..... 3.05 kw.

Thus recapitulating

a. Windage plus bearing and brush friction	3.80 kw.
b. Core loss	2.75 kw.
c. I^2R and brush loss	14.00 kw.
d. Load loss	6.05 kw.
e. I^2R shunt field	3.05 kw.
Total	29.65 kw.

$$\text{True Eff.} = \frac{605}{605 + 29.65} \times 100 = 95.33\%$$

Motor Output. Illustrating by example the method of determining main motor horsepower output, based upon known input readings, assume, for this example, that from meter readings taken from the circuit instruments the following data are obtained:

Terminal volts	560
Armature amps	1080
Motor speed	700
Motor field amps	29.1

The input is thus, volts × amps..... 605 kw.

Having obtained the input, then output is obtained by deducting the losses which are determined as follows:

a. Windage plus bearing and brush friction, as read directly from Fig. 16W at 700 r.p.m..... 3.30 kw.

b. Core loss is determined by use of curves Fig. 11W and 12W as follows: First, subtract from the terminal voltage as read (560 volts) the volts drop as read from Fig. 11W at 1080 amps. hence

$$E = 560 - 13 = 547$$

Using 547 volts, core loss may be read directly from Fig. 12W at 700 r.p.m. thus..... 2.55 kw.

(Interpolation may be required for such readings of motor speed as not shown by the family of curves on Fig. 12W.)

c. I^2R (copper) loss and brush loss are read directly from the upper curve on Fig. 13W at 1080 amps. thus.....14.0 kw.

d. Stray load loss is taken at 1% of input, thus 1% of 605 kw..... 6.05 kw.

Note: For simplicity of calculation stray load loss is taken at 1% of input instead of output.

Summarizing the foregoing losses:

a. Windage plus bearing and brush friction..... 3.30 kw.
b. Core loss..... 2.55 kw.
c. I^2R and brush loss.....14.00 kw.
d. Load loss..... 6.05 kw.

Total.....25.90 kw.

Kw. Output = 605 − 25.90 = 579.10

$$\frac{579.10}{.746} = 776.27 \text{ hp.}$$

Main Motor Efficiency. True main motor efficiency (as determined by the separate loss method) is expressed by the relation

$$\text{Eff.} = \frac{\text{Input} - \text{losses}}{\text{Input}}$$

It will be noted from the foregoing computation that neither the shunt field input nor loss was included, since this loss is not chargeable to the horsepower output. It is, instead, furnished as excitation loss directly from the excitation circuit, i.e., the overhung exciter. But for purposes of expressing efficiency of the motor in the true meaning of overall efficiency, then field input and loss is also included, and may be read directly from Fig. 14W at 27 amps..... 3.27 kw.

Thus recapitulating

a. Windage plus bearing and brush friction..... 3.30 kw.
b. Core loss..... 2.55 kw.
c. I^2R and brush loss.....14.00 kw.
d. Load loss..... 6.05 kw.
e. I^2R shunt field..... 3.27 kw.

Total.....29.17 kw.

$$\text{True Eff.} = \frac{605 + 3.27 - 29.17}{605 + 3.27} \times 100 = 95.20\%$$

Exciter Efficiency. Assume for this example that the following readings were taken from the circuit instruments:

Terminal volts.....120
Armature amperes.....200
Exciter speed.....375
Exciter field amperes.....6.05
The output = volts × amps = 120 × 200 = 24 kw.

Having the output, then the input is obtained by adding the losses, which are determined as follows:

The windage and friction of the exciter will be omitted in this calculation as it is included in the windage and friction curve Fig. 14W for the main propulsion generator, and is charged against the main generator.

1. Core loss is determined by use of curves, Figs. 19W and 20W, as follows: First add to the terminal voltage as read (120 volts) the volts drop as read from Fig. 19W at 200 amperes, hence

E = 120 plus 15.1 = 135.1 volts

Using 135.1 volts core loss may be read directly from Fig. 20W at 375 r.p.m..... .180 kw.

(Interpolation may be required for such readings of exciter speed as not shown by the curves on Fig. 20W.)

2. I^2R (copper) loss and brush loss are read directly from the upper curve on Fig. 21W at 200 amps. thus..... 3.100 kw.
3. Shunt I^2R loss is read directly from Fig. 22W..... .39 kw.
4. Stray load loss is taken at 1% of the output, thus 1% of 24..... .24 kw.

Summarizing the foregoing losses:

1. Core loss..... .180 kw.
2. I^2R and brush loss..... 3.100 kw.
3. Shunt I^2R..... .390 kw.
4. Load loss..... .240 kw.

Total..... 3.910 kw.

Kw. input = output plus losses = 24 plus 3.91 = 27.91 Kw.

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{24}{27.91} \times 100 = 86.00\%$$

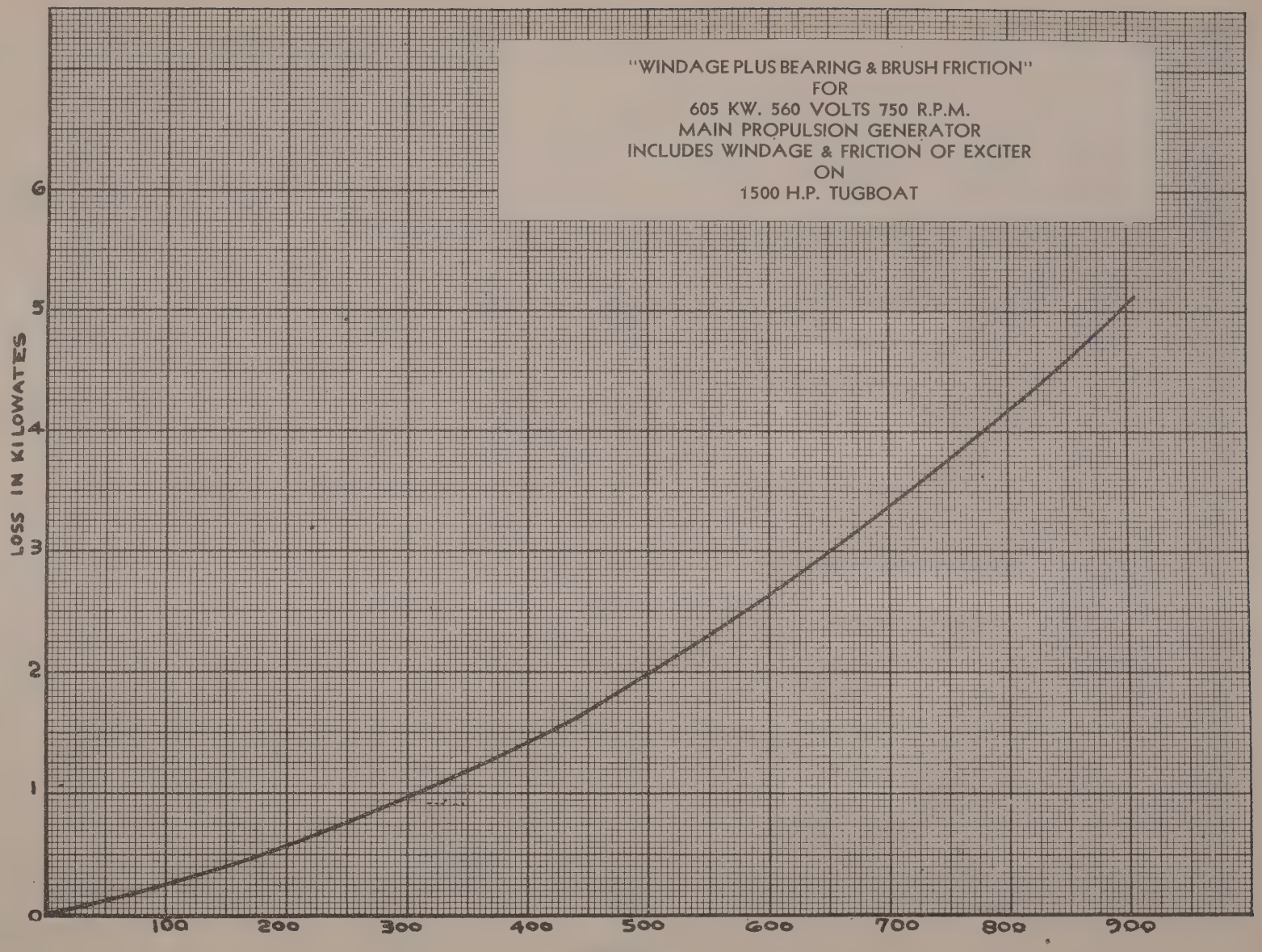


Fig. 10W
Main Generators—Windage and Friction Losses

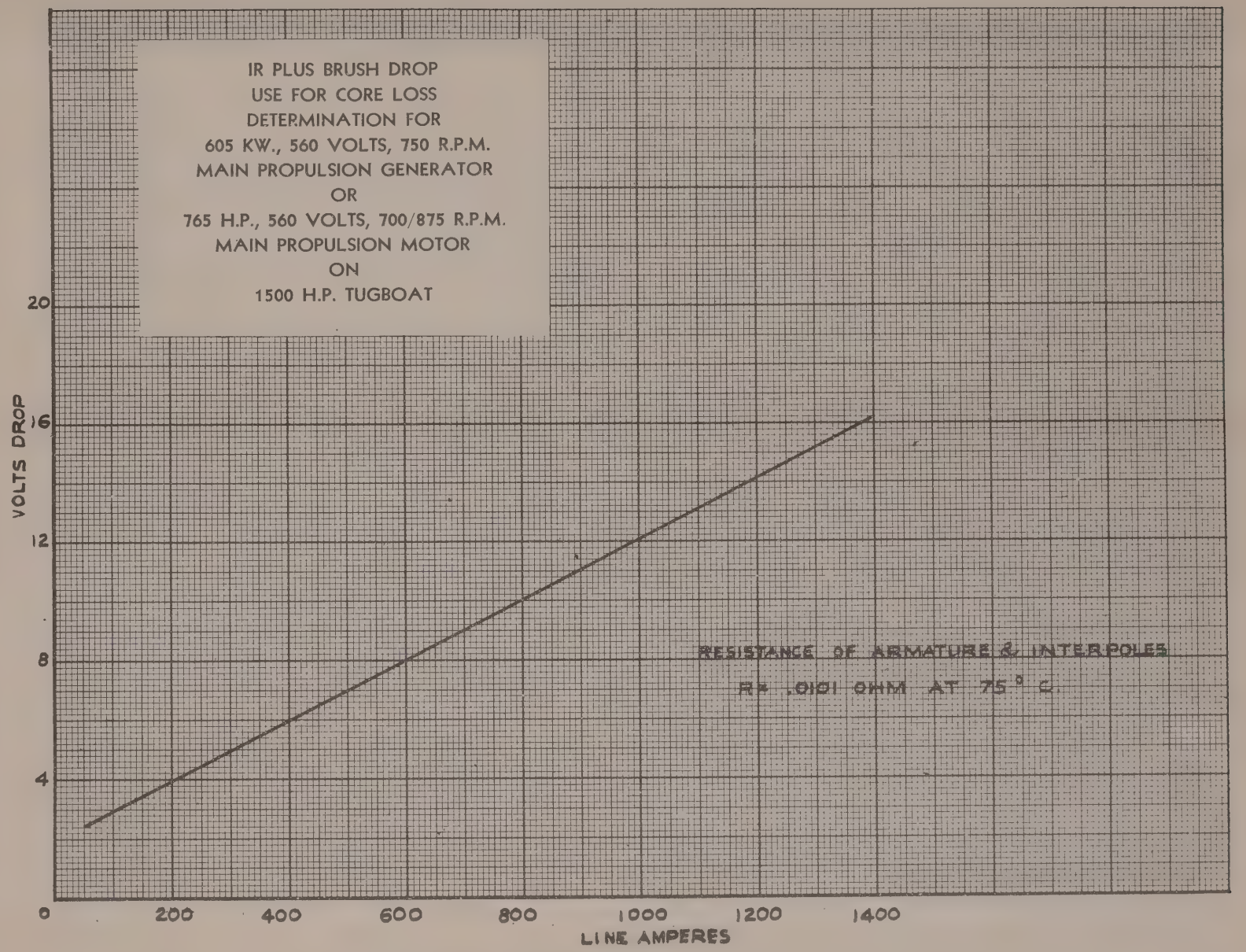


Fig. 11W
Main Generators and Motors—IR Plus Brush Drop

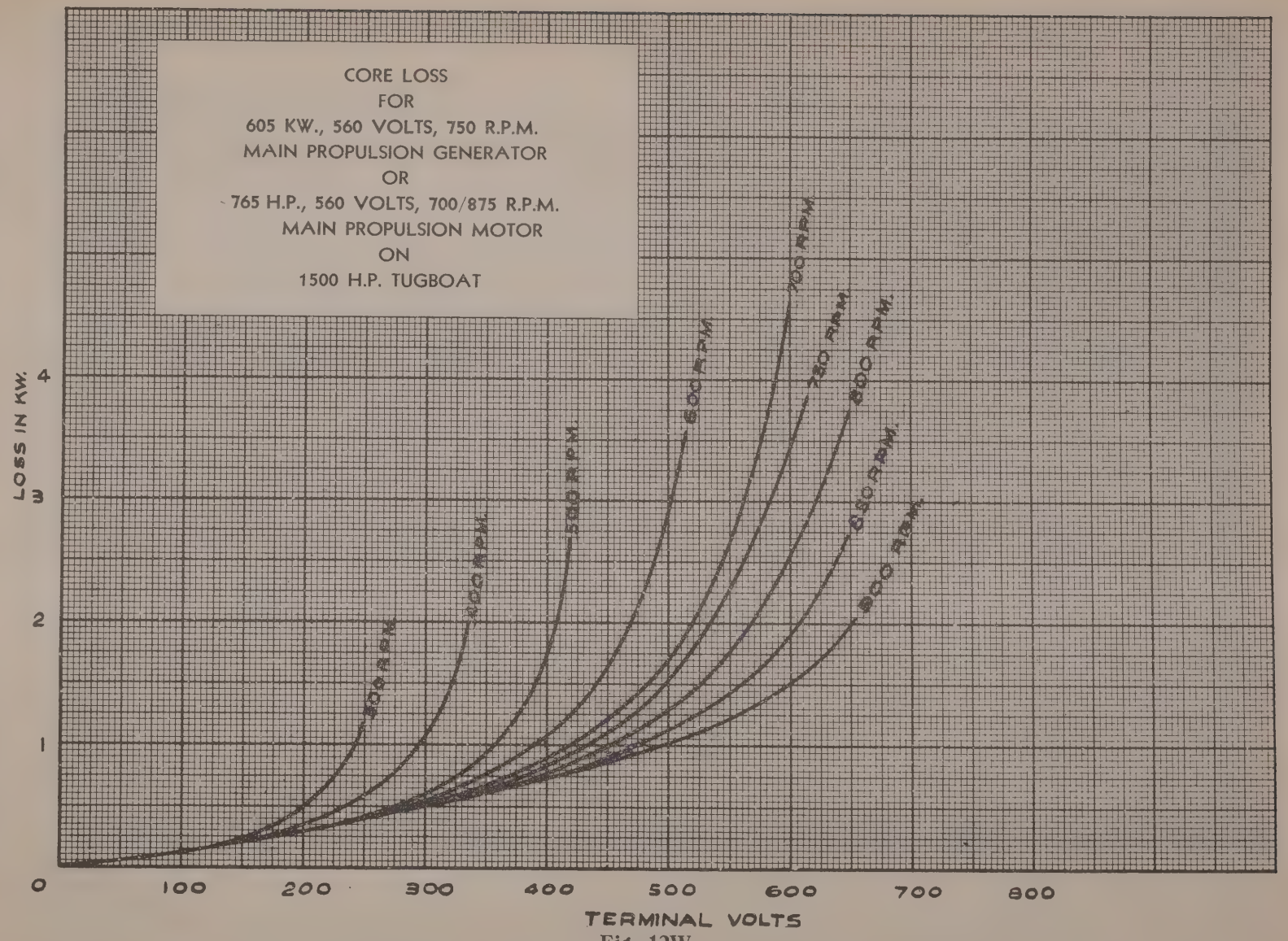


Fig. 12W

Main Generators and Motors—Core Loss—Before reading core loss, add the IR drop from Fig. 11W to terminal voltage for the generators and subtract the IR drop for the motors.

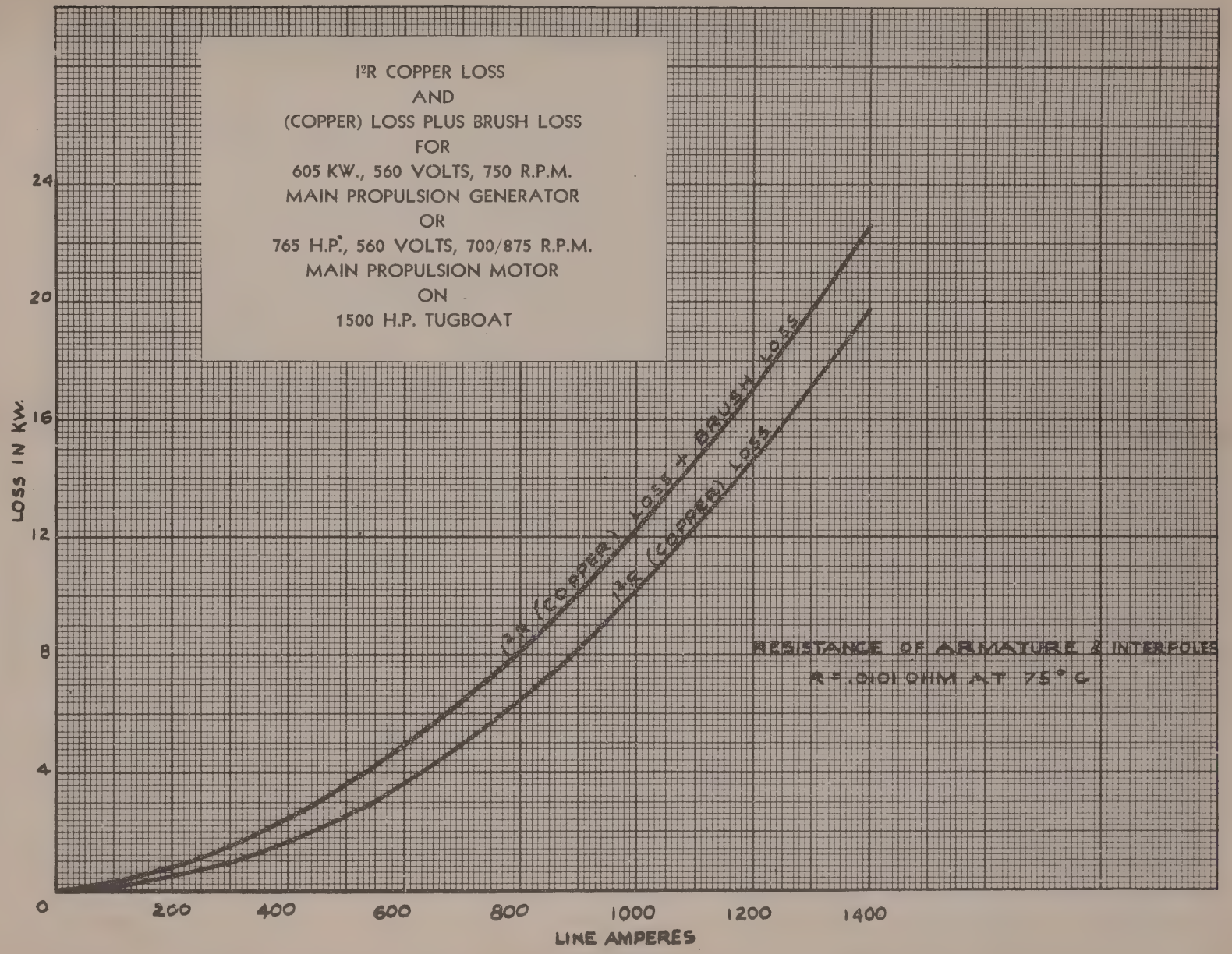


Fig. 13W

Main Generators and Motors—Copper and Brush Losses

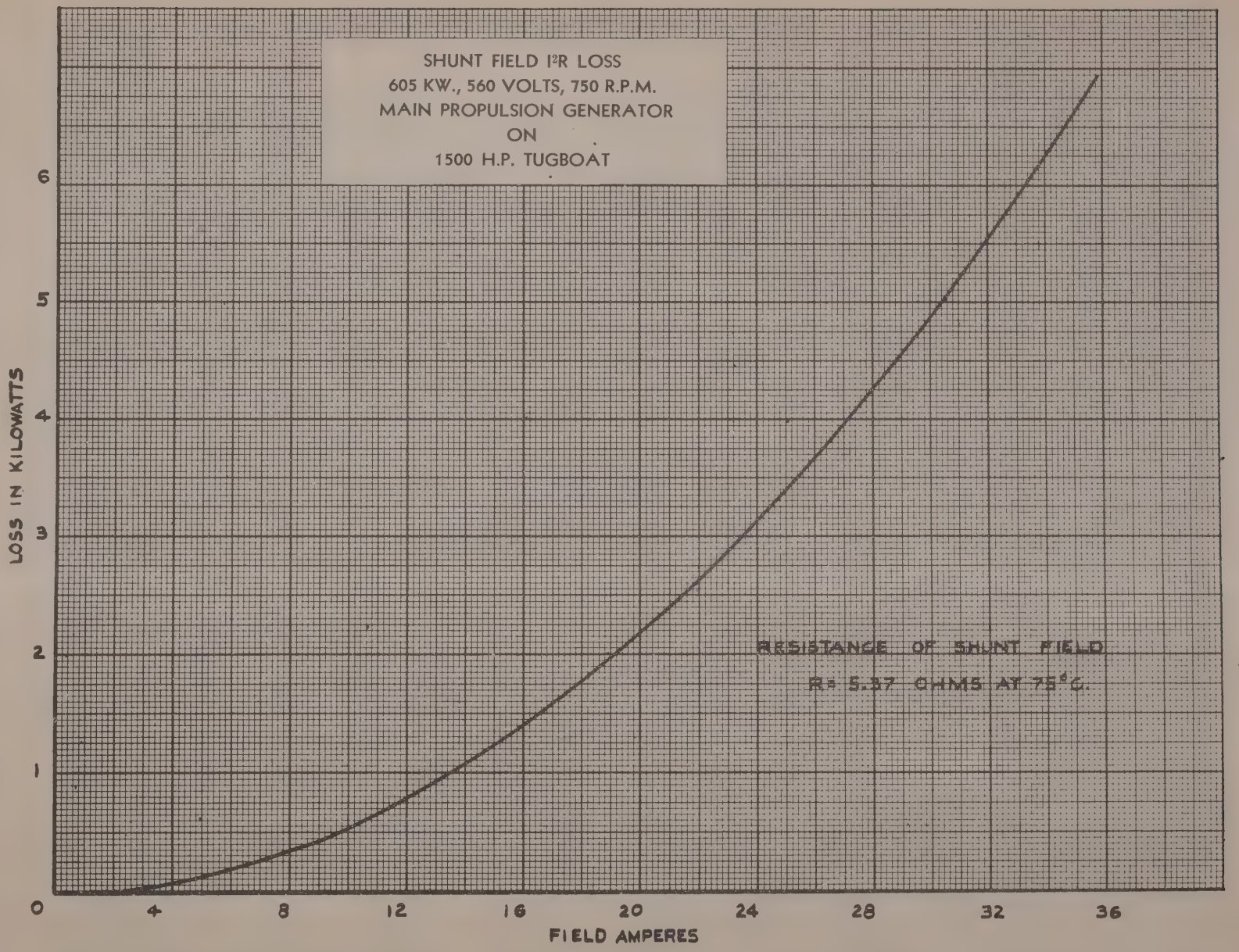


Fig. 14W
Main Generators—Shunt Field Loss

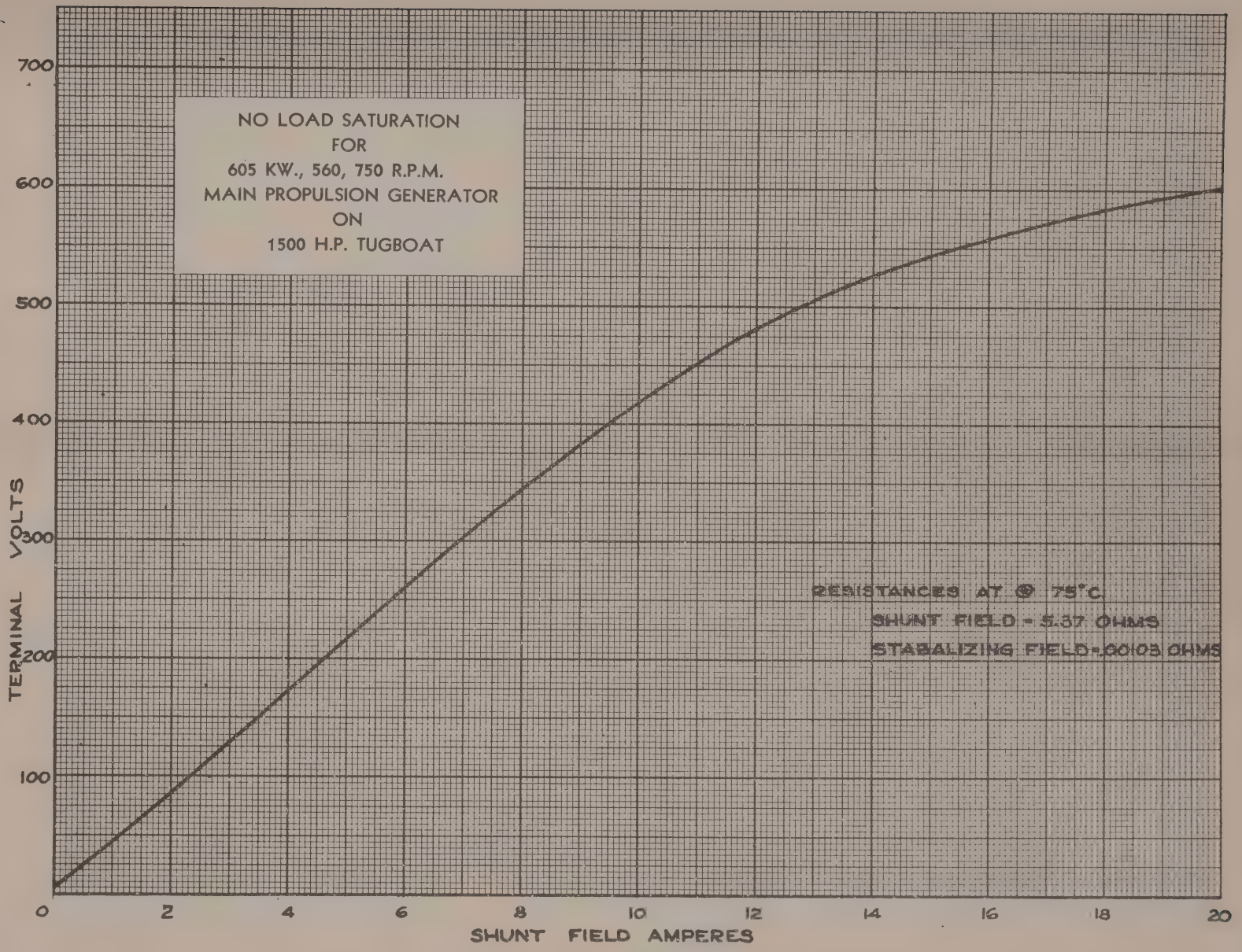


Fig. 15W
Main Generators—No Load Saturation Curve

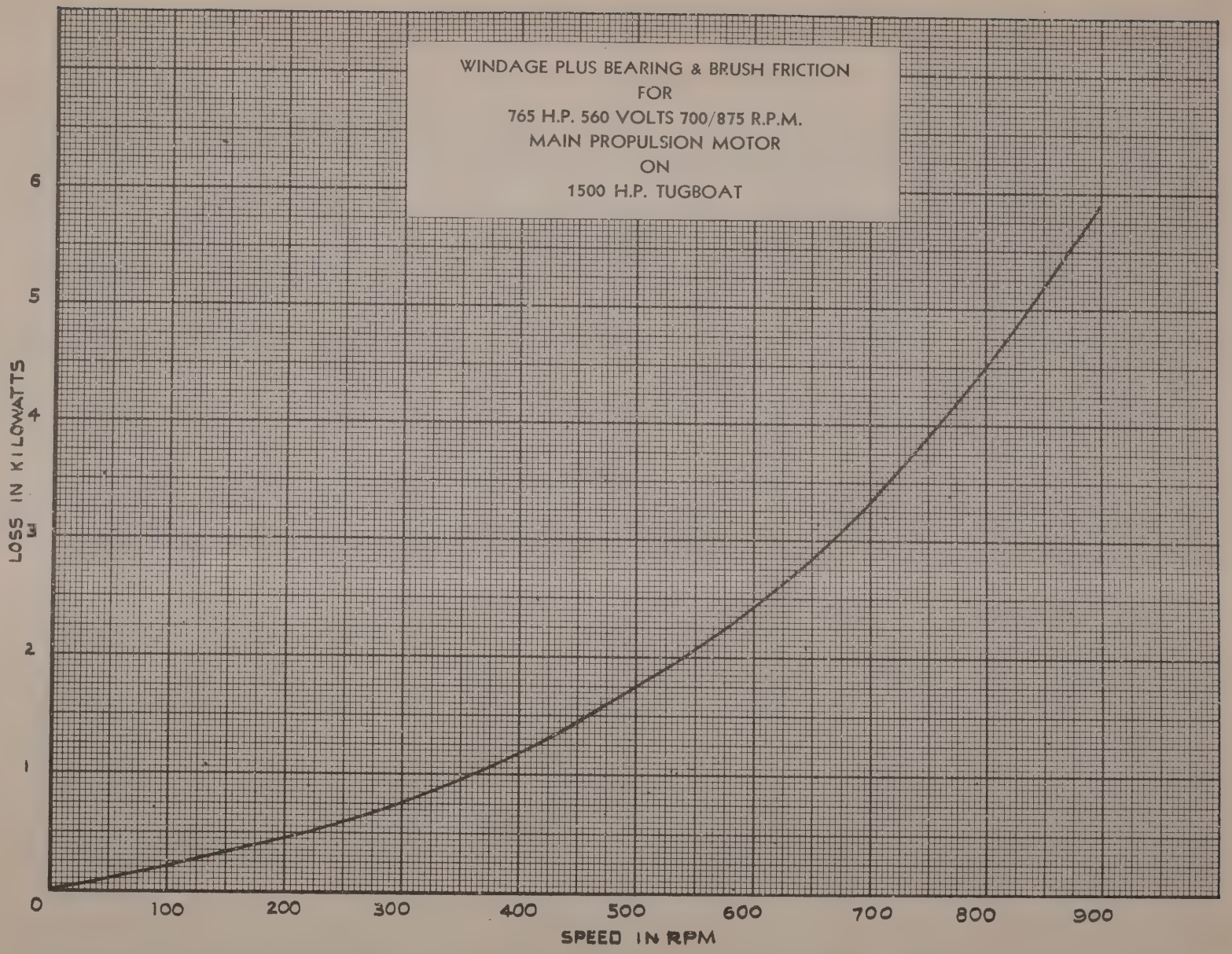


Fig. 16W
Main Motors—Windage and Friction Losses

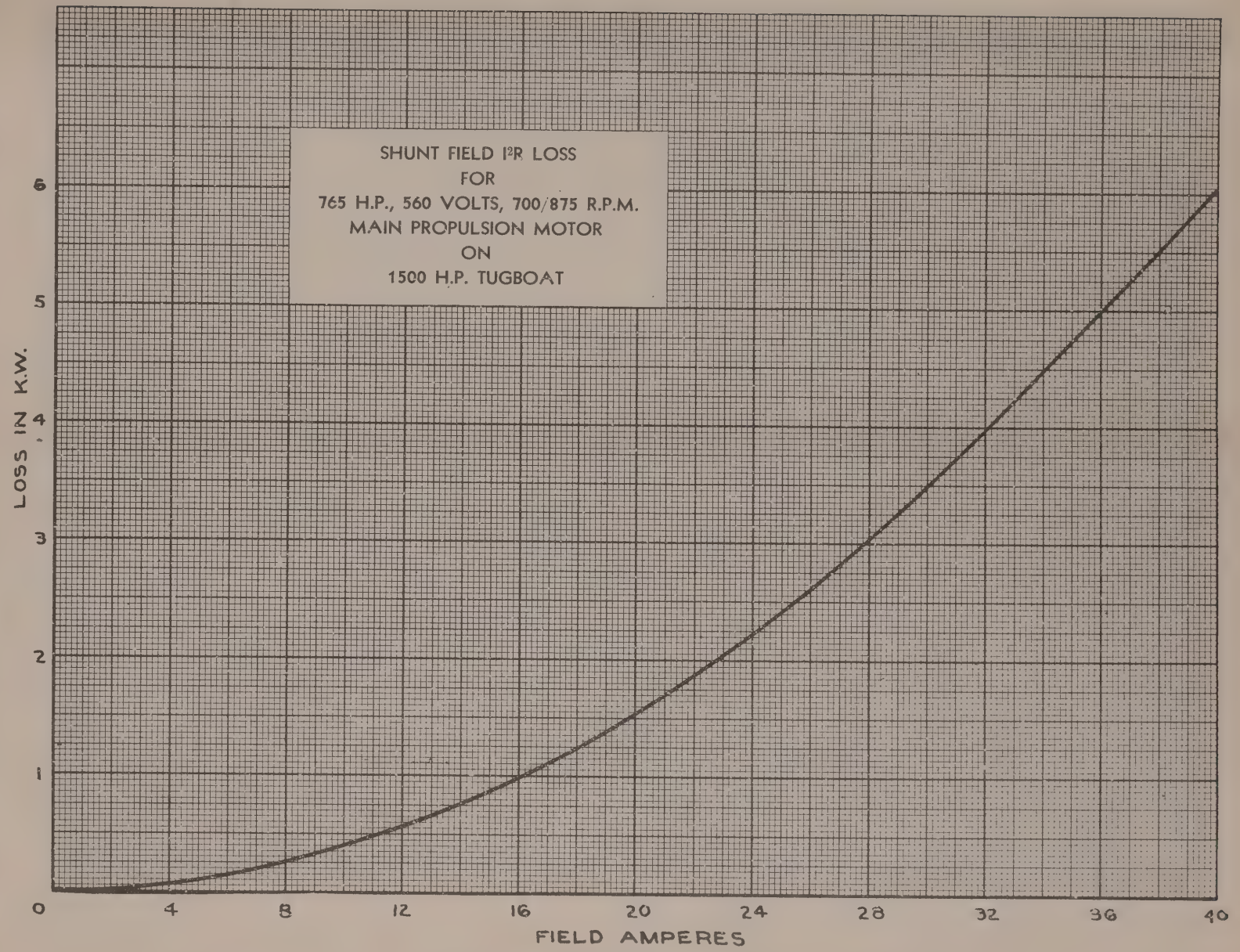


Fig. 17W
Main Motors—Shunt Field Loss

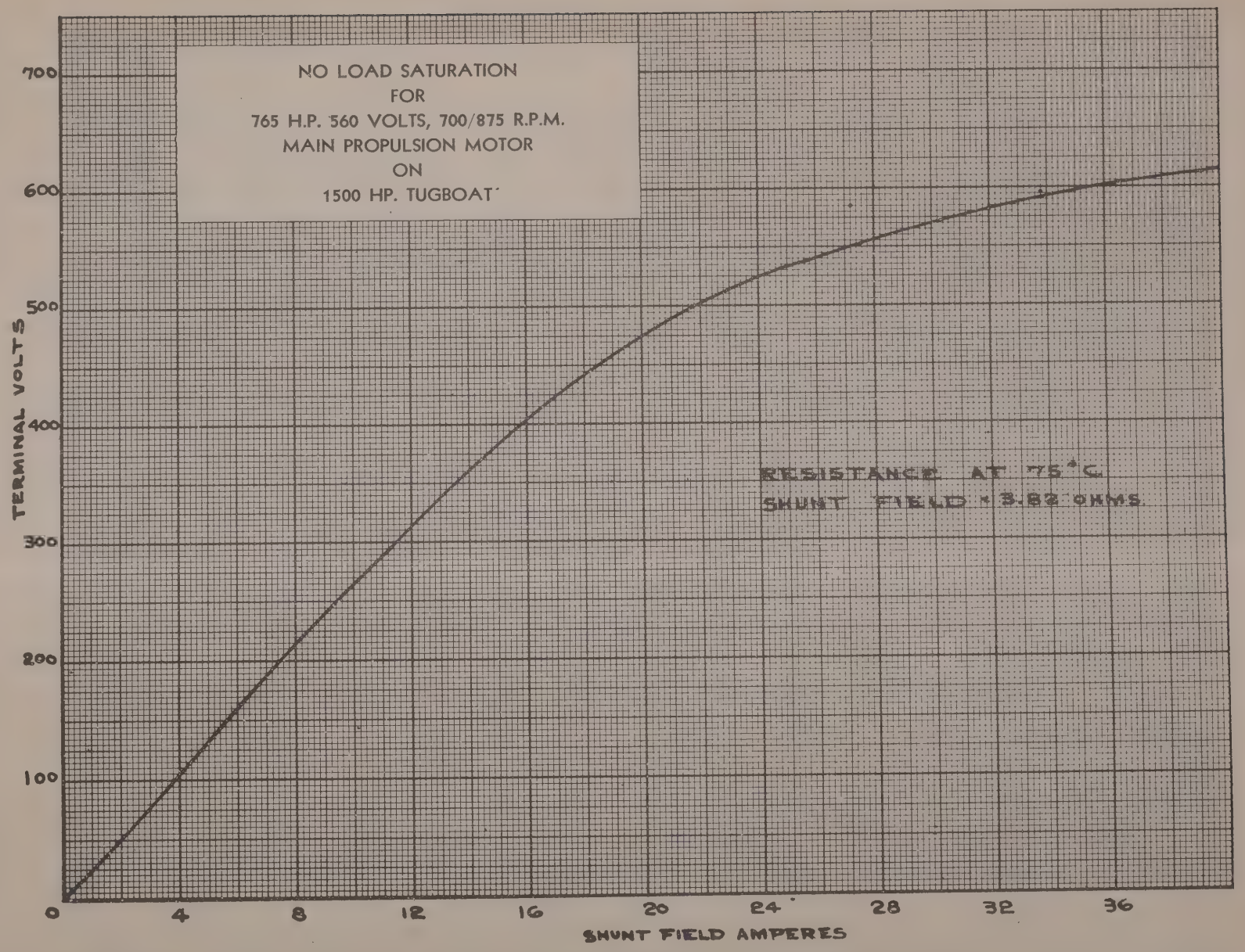


Fig. 18W
Main Motors—No Load Saturation Curve

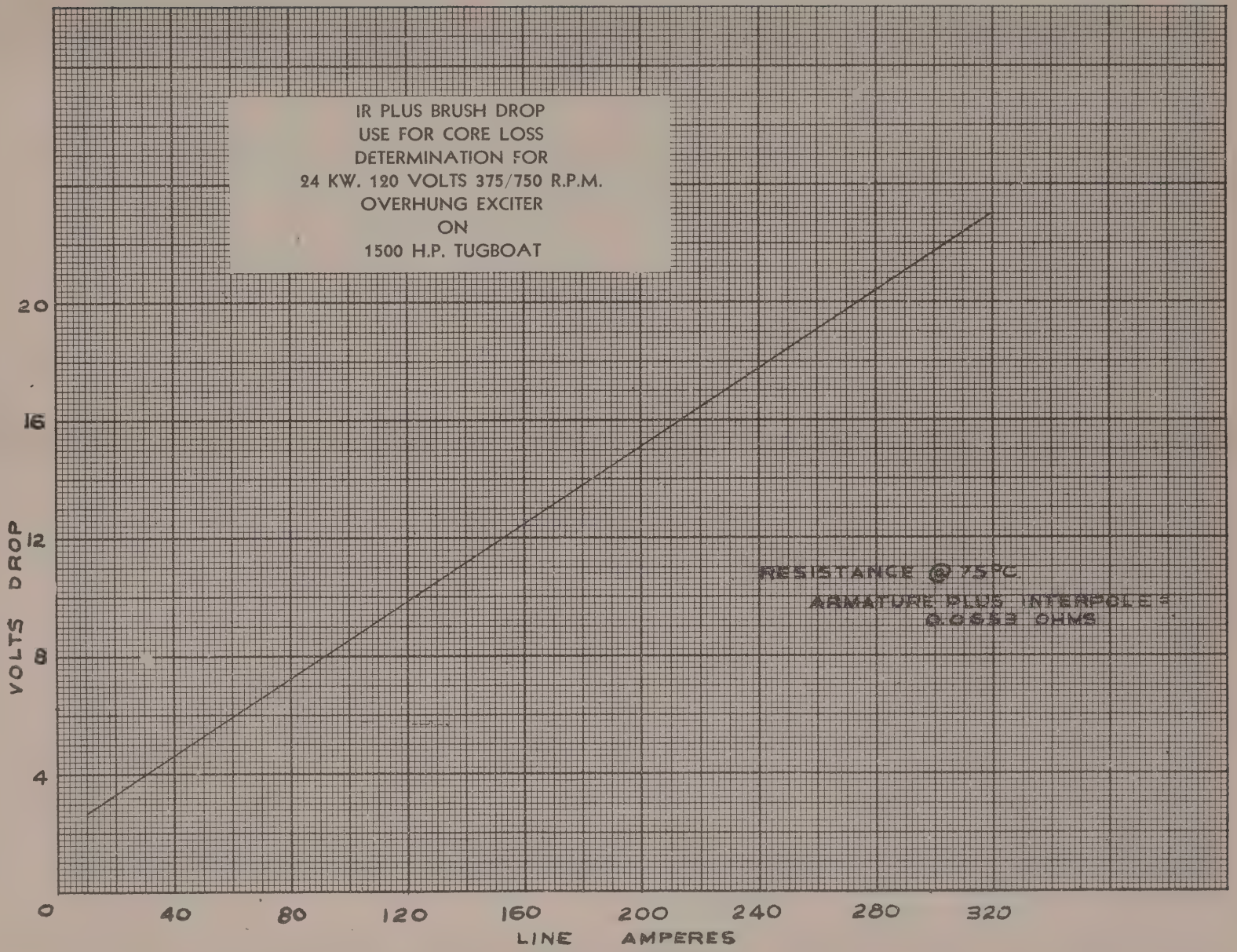


Fig. 19W
Exciters—IR Plus Brush Drop

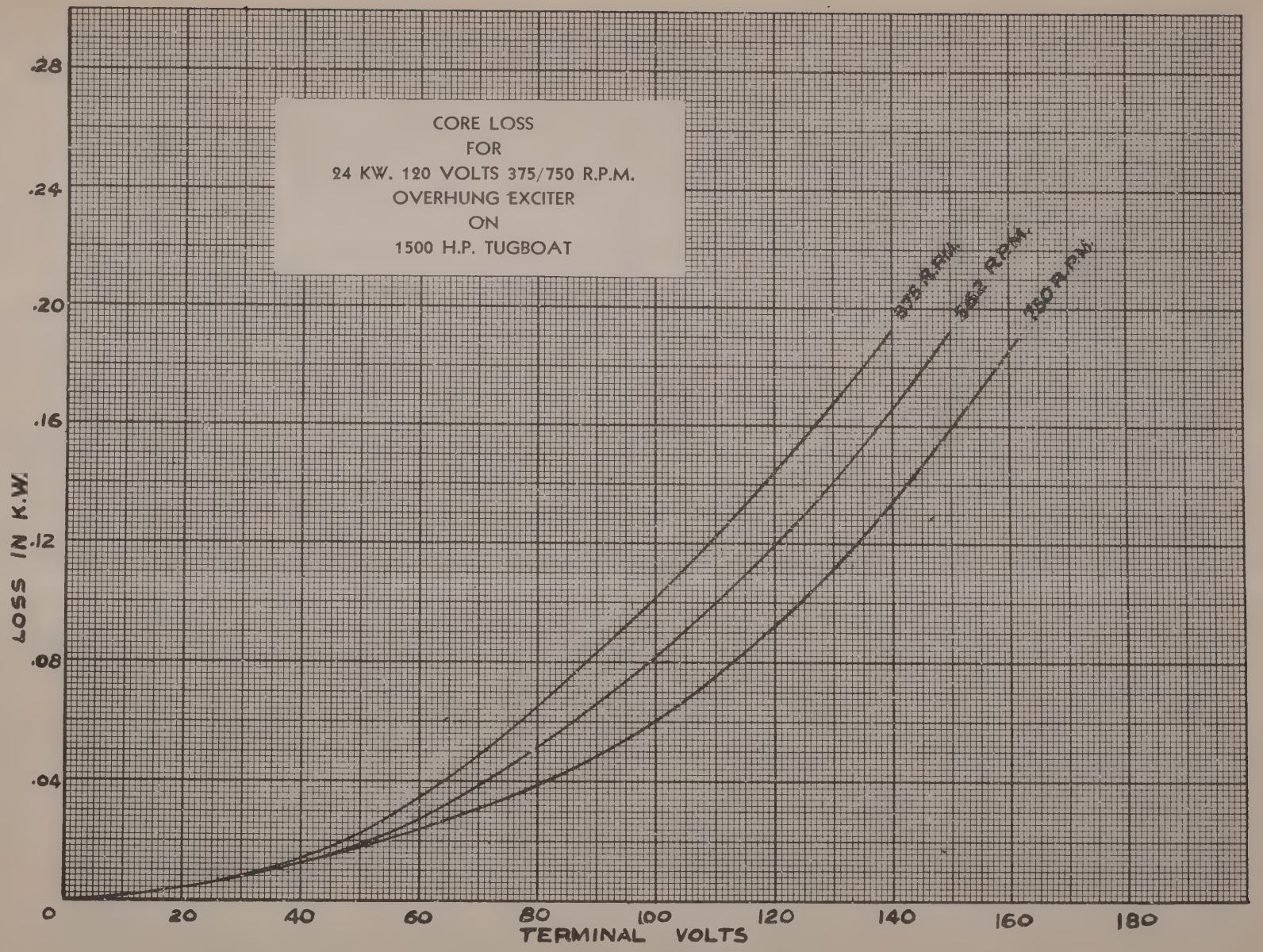


Fig. 20W

Exciters—Core Loss—Before reading core loss, add IR drop from Fig. 19W to the terminal voltage.

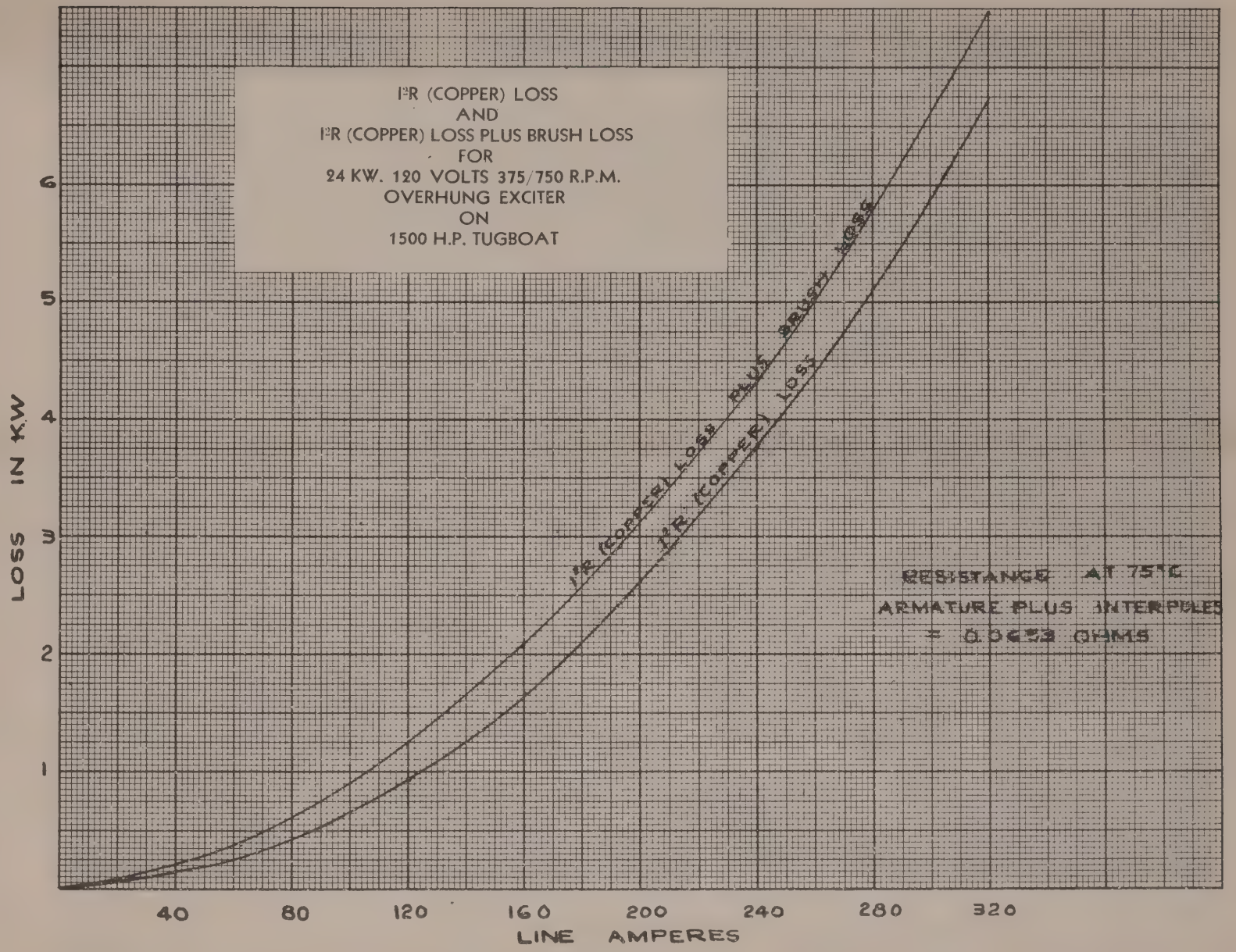


Fig. 21W
Exciters—Copper Losses

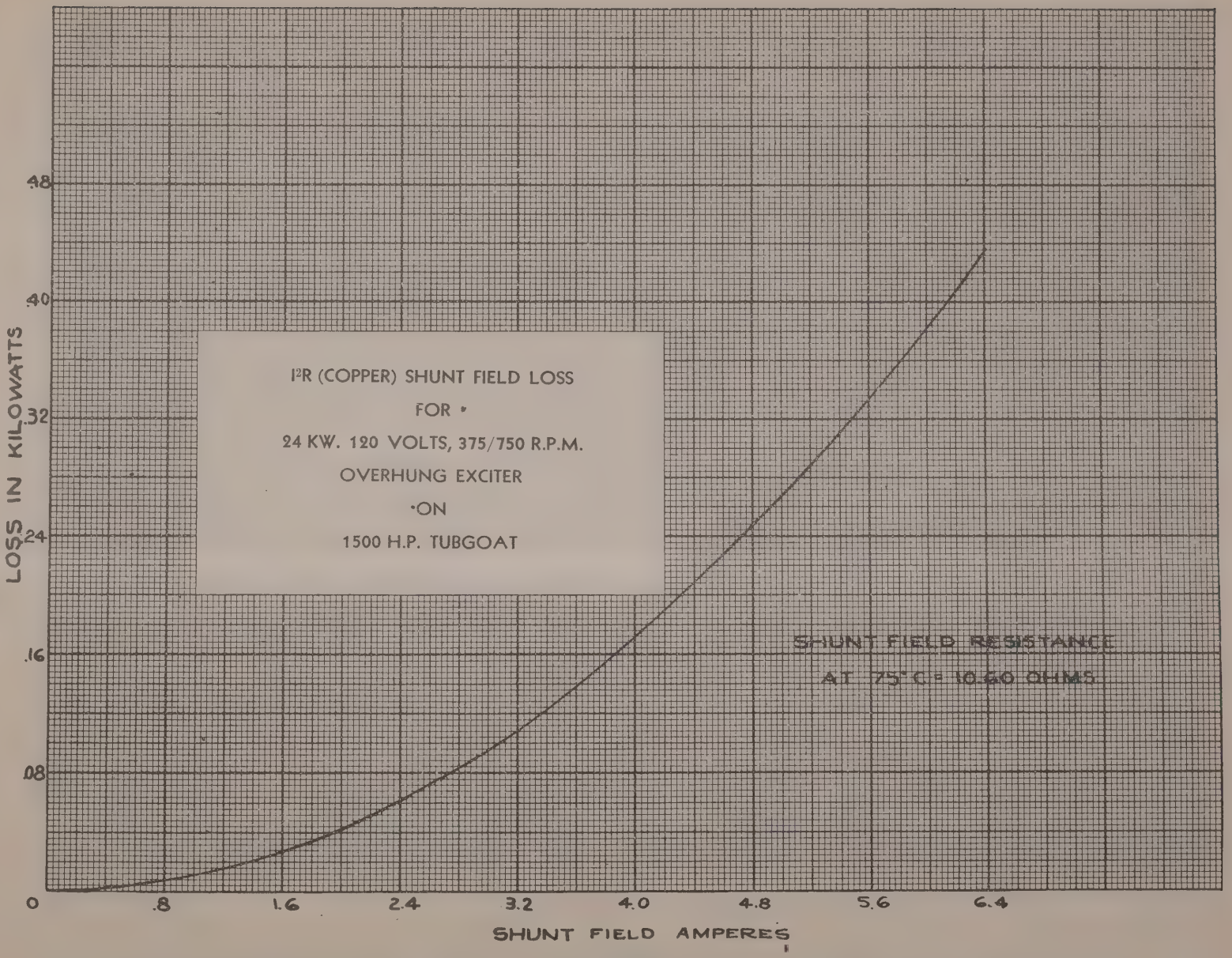


Fig. 22W
Exciters—Shunt Field Loss

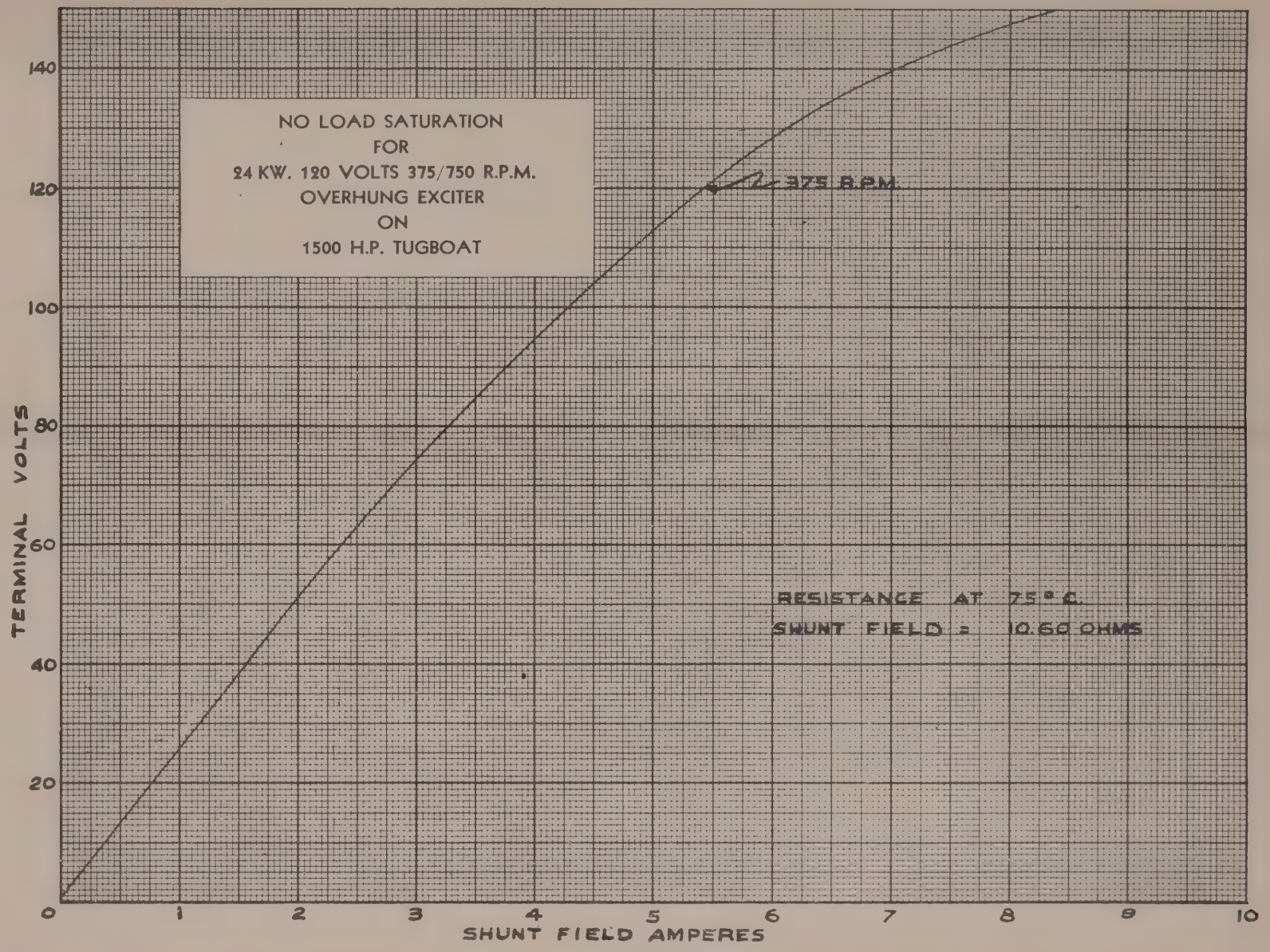


Fig. 23W
Exciters—No Load Saturation Curve

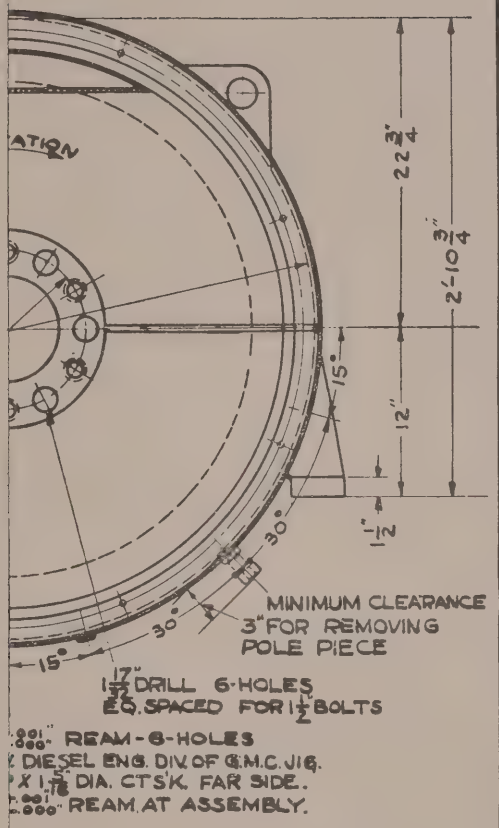
SPARE PARTS

Main Propulsion Motor and Generator

Item No.	*No. of Sets*	*No. per Set*	*Name of Part*	*Allis-Chalmers Drawing No.*
1	1/6	6	Generator Field Coil Assembly	K-164220
2	1/6	6	Motor Field Coil Assembly No. 2	K-164263
3	1	36	¾" x 1¼" Brush No. 6	G-166997
4	1	6	Brush Bracket Insulating Tube Pt. No. 1	G-164248
5	1/36	36	Brush Holder Pt. No. 2	H-158966
6	1/12	36	Brush Holder Spring	G.125118
7	1	1	SKF Bearing—Medium Series—Self-aligning 1319	Cat. No. 205-B; page 15
8	1	1	Bearing Puller	K-169974

Overhung Exciter

9	1/10		Field Coil Assembly	J-163188
10	1	10	⅝" x 1¼" Brush No. 5S	G-166997
11	1/10	10	Brush Holder Assembly No. 2	H-156970
12	3/10	10	Brush Holder Spring	G-156969
13	1	10	Brush Bracket Insulating Tube Pt. No. 3	G-164248



24W

rator and Exciter

Fig. 24W

SPARE PARTS

Main Propulsion Motor and Generator

Item No.	*No. of Sets*	*No. per Set*	*Name of Part*	*Allis-Chalmers Drawing No.*
1	1/6	6	Generator Field Coil Assembly	K-164220
2	1/6	6	Motor Field Coil Assembly No. 2	K-164263
3	1	36	¾" x 1¼" Brush No. 6	G-166997
4	1	6	Brush Bracket Insulating Tube Pt. No. 1	G-164248
5	1/36	36	Brush Holder Pt. No. 2	H-158966
6	1/12	36	Brush Holder Spring	G.125118
7	1	1	SKF Bearing—Medium Series—Self-aligning 1319	Cat. No. 205-B; page 15
8	1	1	Bearing Puller	K-169974

Overhung Exciter

9	1/10		Field Coil Assembly	J-163188
10	1	10	⅝" x 1¼" Brush No. 5S	G-166997
11	1/10	10	Brush Holder Assembly No. 2	H-156970
12	3/10	10	Brush Holder Spring	G-156969
13	1	10	Brush Bracket Insulating Tube Pt. No. 3	G-164248

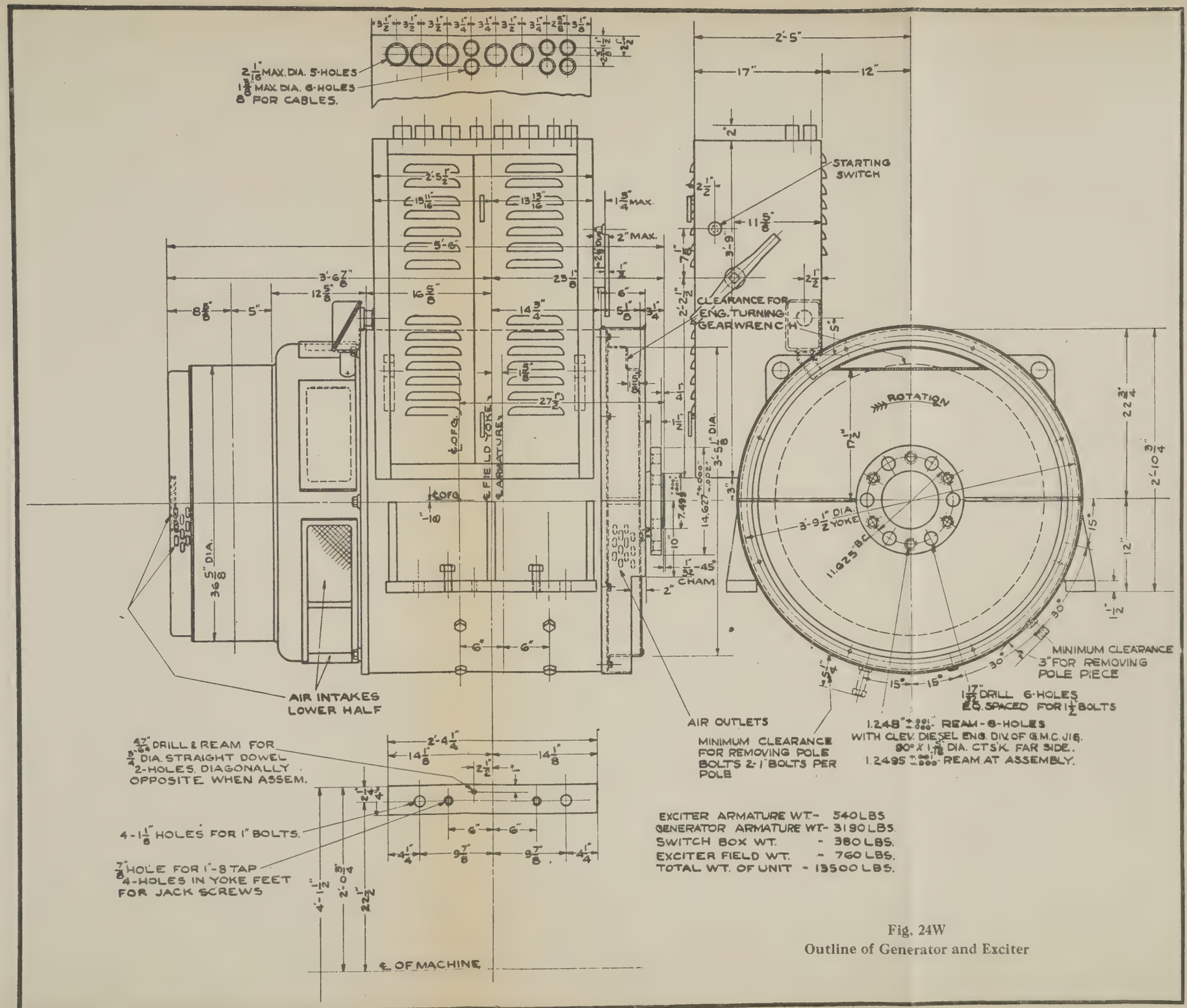

2 1/16" MAX. DIA. 5-HOLES
1 3/8" MAX. DIA. 6-HOLES FOR CABLES.
STARTING SWITCH
CLEARANCE FOR ENG. TURNING GEAR WRENCH
ROTATION
AIR INTAKES LOWER HALF
AIR OUTLETS
MINIMUM CLEARANCE FOR REMOVING POLE BOLTS 2-1" BOLTS PER POLE
MINIMUM CLEARANCE 3" FOR REMOVING POLE PIECE
1 7/8" DRILL 6-HOLES EQ. SPACED FOR 1 1/2" BOLTS
1.248" REAM-6-HOLES WITH CLEV. DIESEL ENG. DIV. OF G.M.C. J16. 90° X 1 5/16" DIA. CT'SK. FAR SIDE.
1.2495 REAM AT ASSEMBLY.
4-1 1/8" HOLES FOR 1" BOLTS.
7/8" HOLE FOR 1"-8 TAP 4-HOLES IN YOKE FEET FOR JACK SCREWS
3/4" DRILL & REAM FOR 3/4" DIA. STRAIGHT DOWEL 2-HOLES, DIAGONALLY OPPOSITE WHEN ASSEM.
℄ OF MACHINE
℄ OF FIELD YOKE & ARMATURE
EXCITER ARMATURE WT- 540 LBS.
GENERATOR ARMATURE WT- 3190 LBS.
SWITCH BOX WT. - 380 LBS.
EXCITER FIELD WT. - 760 LBS.
TOTAL WT. OF UNIT - 13500 LBS.

Fig. 24W
Outline of Generator and Exciter

Fig. 24W

CE DRAWINGS	DRG. NO
E (MOTOR)	K-159822
E (GENERATOR)	K-159937
SHAFT	J-159827
FAN (MOTOR)	K-163619
FAN (GENERATOR)	K-163618
END SHIELD	K-163196
OUSING (MOTOR)	H-163467
OUSING (GENERATOR)	K-163177
SSEMBLY	H-159984

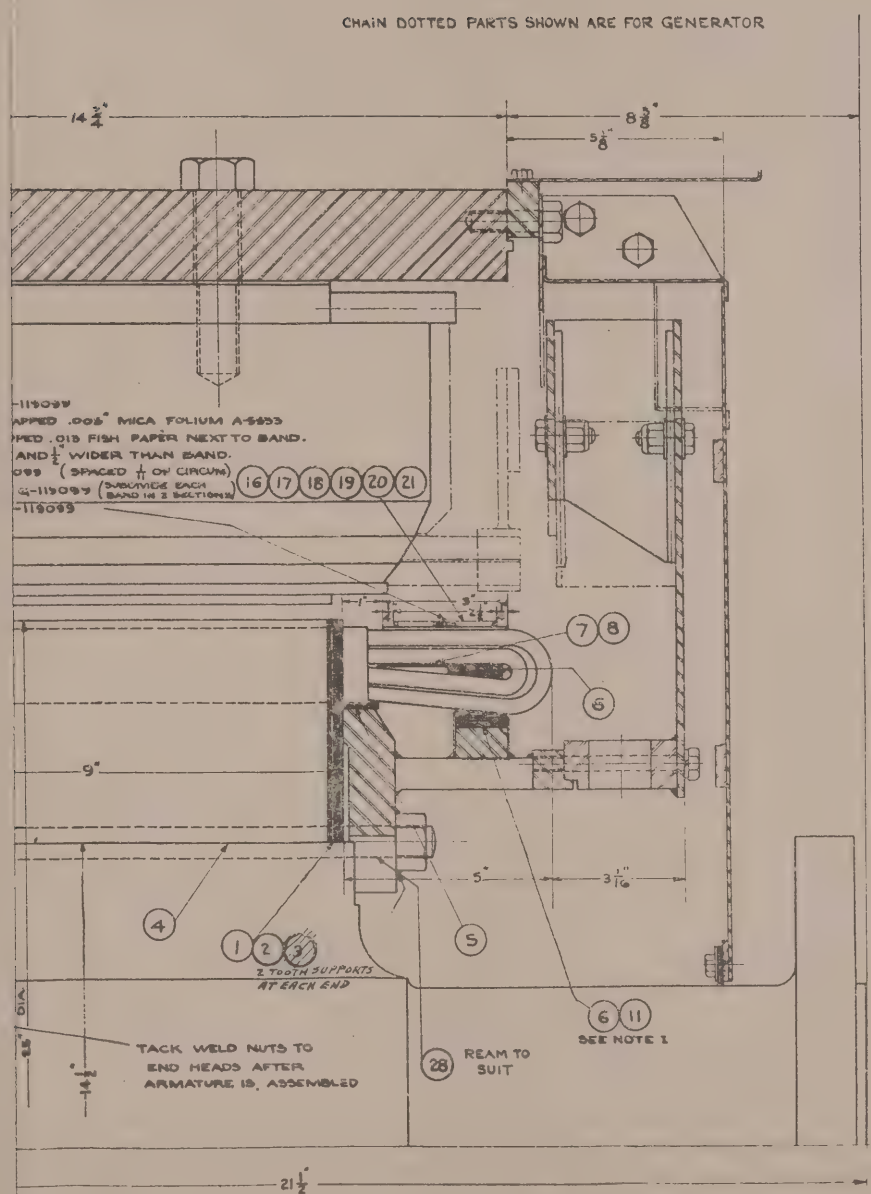


Fig. 25W
Generator and Motor Assembly

Fig. 25W

ITEM	REQ.	SIZE & NAME	MAT.	DRG. NO.	STK.	WT.
1	12	.037B ARMATURE PUNCHING ITEM #2	SH. ST.	J-164244	PT. (48)	22#
2	4	ARMATURE TOOTH SUPPORT ITEM #1		G-163463		20#
3	1	~~.039" ARMATURE PUNCHING ITEM #6~~		~~H-160830~~		18
4	1229	.014" ARMATURE PUNCHING ITEM #3	SEE ORDER	J-164244	PT. (85)	1657#
5	84	1/16 x 7" x 30" LG. INSULATION	BAKELITE VULCOID OR EQUAL	A-3675		
6	48	1/16" X 1 1/2" X 30" LG. "	ASB. FIB. PLEX. MICA	A-3218		
7	3	.010" X 3 3/4" X 30" LG. "				
8	3	.012" X 3 3/4" X 30" LG. "	VARNISHED GLASS CLOTH			
9	9	.010" X 3 3/4" X 30" LG. "	PLEX. MICA	A-3218		
10	9	.012" X 3 3/4" X 30" LG. "	VARNISHED GLASS CLOTH			
11	116 YDS.	.010" X 3/4" WIDE " HALF LAPPED	GLASS TAPE	A-8113		
12	12	1 1/8 OD X 7/8" ID X 1 5/32" LG. TUBE	BAKELITE GRADE XX	B-5892		
13	104	.005" X 3 1/2" X 6" LG. INSULATION	MICA FOLIUM	A-5933		
14	26	.013" X 3 1/2" X 6" LG. " "	FISH PAPER			
15	13	.005" X 1 1/2" X 3" LG. " BETW. BAND & CLIPS	MICA FOLIUM	A-5933		
16	6	.060" X 2" X 30" LG. "	PLEX. MICA	A-3218		
17	104	.005" X 3" X 6" LG. "	MICA FOLIUM	A-5933		
18	26	.013" X 3" X 6" LG. "	FISH PAPER			
19	13	.005" X 1 1/2" X 2 1/4" LG. " BETW. BAND & CLIPS	MICA FOLIUM	A-5933		
20	400 FT.	#10 B.&S. GA. (.1019") BANDWIRE (TINNED)	IRON MAGNETIC	G-147972		11#
21	1	1/16" X 1" X 14 FT. LG. STRIP (CUT TO SUIT FOR CLIPS)	TERNE PLATE TINNED STEEL			
22	4	.010" X 3" X 48" LG. INSULATION	PLEX. MICA	A-3218		
23	2	4" X 48" LG. "	18 OZ. DUCKING	A-4163		
24	116 YDS.	GLASS CORD #310		G-48751		
25	2	.010" X 6 3/4" X 40" LG. INSULATION	PLEX. MICA	A-3218		
26	58 YDS.	.005" X 3/4" WD. INSULATION HALF LAPPED	GLASS TAPE	A-8114		
27	12	INSULATING SHIELD PT. NO. 29		G-146516		

ITEM	REQ.	SIZE & NAME	MAT.	DRG. NO.	STK.	WT.
28	8	5/16 DIA. X 2 1/2" LG. STUD BOLT PT. NO. 12		G-157175		
29	1	1/8" PIPE PLUG	BRASS	S-5076	1783	
30	12	3/8" CROSS CONN. STUD PT. NO. 11		G-108531		
31	42	5/16" X 1 1/2" LG. HEX. HD. TAP BOLT	CAD. PLATED	B-6142	4391	
32	42	5/16" LOCK WASHER	CAD. PLATED	B-6162	7395	
33	6	1/2" X 1" LG. HEX. HD TAP BOLT	CAD. PLATED	B-6142	4648	
34	6	1/2" LOCK WASHER	CAD. PLATED	B-6162	7496	
35	6	1/2" SPECIAL LOCK WASHER #15		G-163328		
36	2	5/16 X 2 1/2" LG. SQ HD OVAL PT SET SCREW	CAD. PLATED	B-5089		
37	2	5/16" HEX. JAM NUT	CAD. PLATED	B-6216	8287	

REFERENCE DRAWINGS	DRG. NO.
FIELD YOKE (MOTOR)	K-159822
FIELD YOKE (GENERATOR)	K-159937
ARMATURE SHAFT	J-159827
ARMATURE FAN (MOTOR)	K-163619
ARMATURE FAN (GENERATOR)	K-163618
ARMATURE END SHIELD	K-163196
BEARING HOUSING (MOTOR)	H-163467
BEARING HOUSING (GENERATOR)	K-163177
BEARING ASSEMBLY	H-159384

CHAIN DOTTED PARTS SHOWN ARE FOR GENERATOR

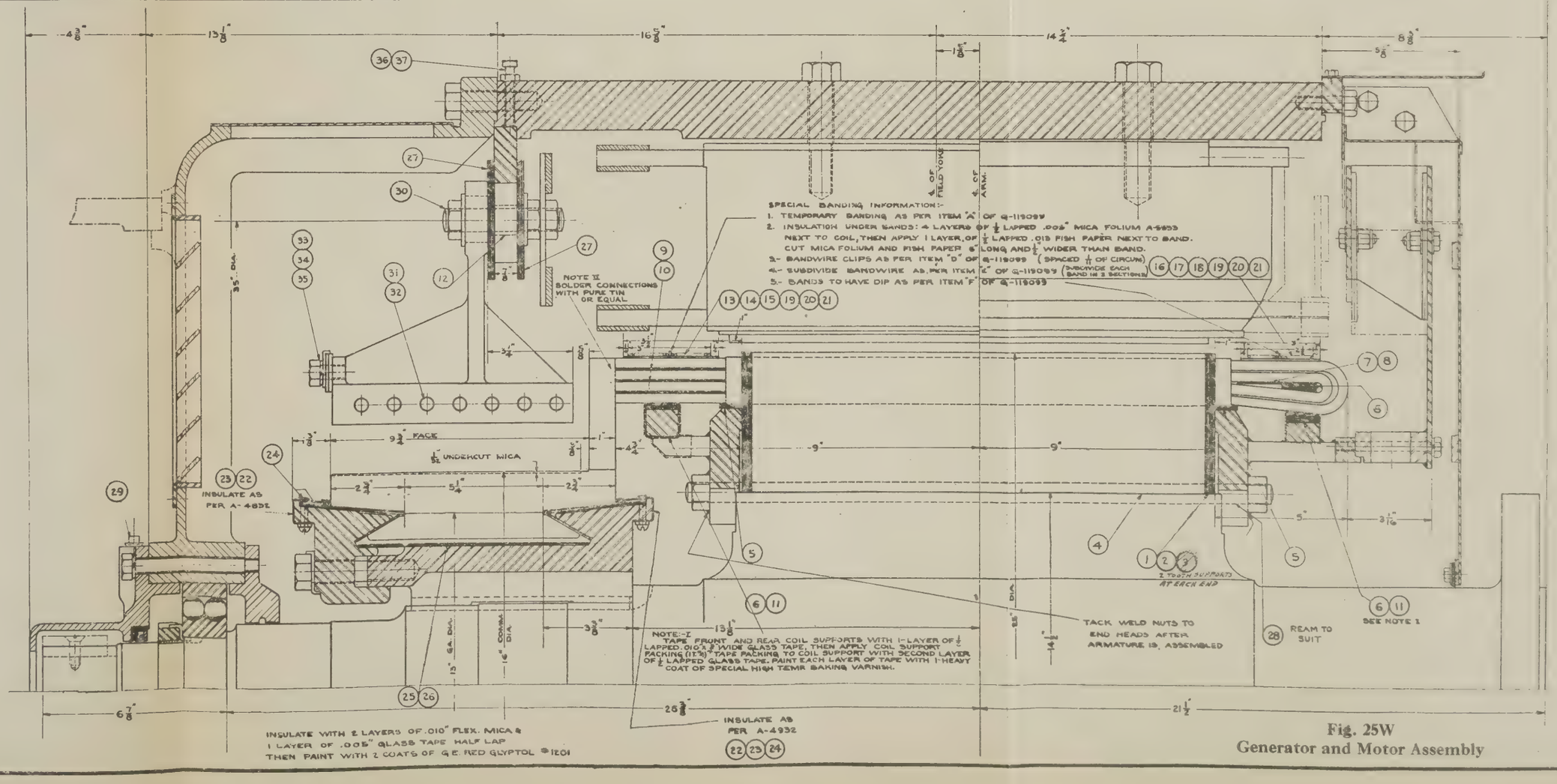

4 3/8"
13 1/8"
16 5/8"
14 2/4"
8 3/8"
1 5/8"
5/8"
4 OF FIELD YOKE
4 OF ARM.
35" DIA.
NOTE II SOLDER CONNECTIONS WITH PURE TIN OR EQUAL
SPECIAL BANDING INFORMATION:-
1. TEMPORARY BANDING AS PER ITEM "A" OF G-119089
2. INSULATION UNDER BANDS: 4 LAYERS OF 1/2 LAPPED .005" MICA FOLIUM A-5933 NEXT TO COIL, THEN APPLY 1 LAYER OF 1/2 LAPPED .013 FISH PAPER NEXT TO BAND. CUT MICA FOLIUM AND FISH PAPER 6" LONG AND 1/2 WIDER THAN BAND.
3- BANDWIRE CLIPS AS PER ITEM "D" OF G-119089 (SPACED 1/4 OF CIRCUM)
4- SUBDIVIDE BANDWIRE AS PER ITEM "E" OF G-119089 (SUBDIVIDE EACH BAND IN 3 SECTIONS)
5- BANDS TO HAVE DIP AS PER ITEM "F" OF G-119089
9 FACE
1/32" UNDERCUT MICA
INSULATE AS PER A-4832
9"
9"
5"
3 1/16"
2 TOOTH SUPPORTS AT EACH END
TACK WELD NUTS TO END HEADS AFTER ARMATURE IS ASSEMBLED
REAM TO SUIT
SEE NOTE 1
NOTE:-I TAPE FRONT AND REAR COIL SUPPORTS WITH 1-LAYER OF 1/2 LAPPED .010" X 3/4" WIDE GLASS TAPE, THEN APPLY COIL SUPPORT PACKING (11/32") TAPE PACKING TO COIL SUPPORT WITH SECOND LAYER OF 1/2 LAPPED GLASS TAPE. PAINT EACH LAYER OF TAPE WITH 1-HEAVY COAT OF SPECIAL HIGH TEMP BAKING VARNISH.
13 1/8"
25" DIA.
14" IN
6 7/8"
26 3/8"
21 1/2"
INSULATE WITH 2 LAYERS OF .010" FLEX. MICA & 1 LAYER OF .005" GLASS TAPE HALF LAP THEN PAINT WITH 2 COATS OF G.E. RED GLYPTOL #1201
INSULATE AS PER A-4932

Fig. 25W
Generator and Motor Assembly

Fig. 25W

NOTES:

I. SPECIAL BANDING INFORMATION
1. TEMPORARY BANDING AS PER ITEM 'A' OF DRG. NO. G-118099
2. INSULATION UNDER BANDS-(4) LAYERS OF 1/2 LAPPED-ITEM NO.11 NEXT TO COIL. THEN APPLY (1) LAYER OF 1/2 LAPPED-ITEM NO.12 NEXT TO BAND.
3. BANDWIRE CLIPS AS PER ITEM 'D' OF DRG. NO. G-118099 (SPACED 1/11 OF CIRCUM.)
4. BANDS TO HAVE DIP AS PER ITEM 'F' OF DRG. NO. G-118099.

II. INSULATE WITH (2) LAYERS ITEM NO.16, AND (1) LAYER OF ITEM NO.17-HALF-LAPPED.

III. PAINT INSIDE OF COMMUTATOR, AND ITEM NO.18 ON OUTSIDE WITH (2) COATS OF G.E. RED GLYPTOL, NO. 1201

IV. TAPE COIL SUPPORT WITH (1) LAYER OF 1/2 LAPPED-ITEM NO. 8. THEN APPLY COIL SUPPORT PACKING ITEM NO.4. TAPE PACKING TO COIL SUPPORT WITH SECOND LAYER OF 1/2 LAPPED-ITEM NO.8. PAINT EACH LAYER OF TAPE WITH ONE HEAVY COAT OF SPECIAL HIGH TEMP. BAKING VARNISH.

V. PACK AS REQUIRED WITH ITEM NO.20, AND SOLDER WITH PURE TIN OR EQUAL.

VI. TO OBTAIN DIP IN BAND, BUILD UP AS REQUIRED WITH ITEM NO.4, TAPE DOWN WITH (1) LAYER OF HALF-LAPPED-ITEM NO.8. PAINT WITH (2) COATS OF SPECIAL HIGH TEMP. BAKING VARNISH.

VII. TREAT ARMATURE AND FIELD AS PER A-6072

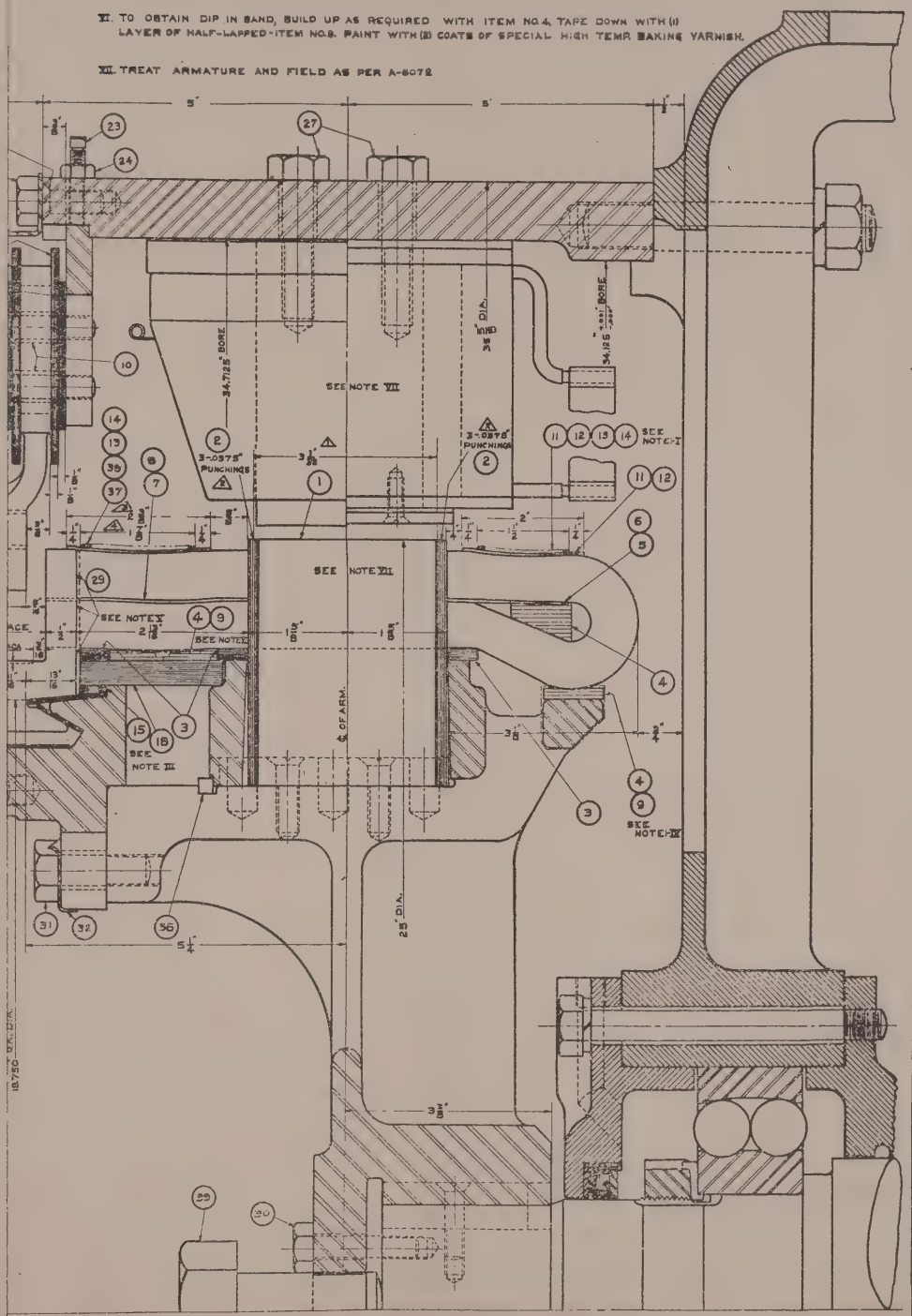


Fig. 26W

Item	Req'd.	SIZE AND NAME	Mat.	Drg. No.
1	164	.018"		
	6	.0375" Armature Punchings Pt. (See D-L)	See Order	H-123425
2	2	Armature Toothsupport It. No. 1	.....	G-163463
3	3	21⅛"I.D.x21½"O.D.x⅛"Lg. Insul. Tube Pt. No. 1	.....	G-163185
4	48	1/16"x1"x30"Lg. Insulation	Bakelite Asbestos Grade AA	A-5675
5	3	.010"x2"x30"Lg. Insulation	Flex. Mica	A-3218
6	3	.012"x2"x30"Lg. Insulation	Varn. Glass Cloth	
7	3	.010"x2½"x30"Lg. Insulation	Flex. Mica	A-3218
8	3	.012"x2⅝"x30"Lg. Insulation	Varn. Glass Cloth	.....
9	40 yds.	.010"x¾" Wide Insulation Half-Lapped	Glass Tape	A-6115
10	20	⅛"O.D.x⅝"I.D.x1¼"Lg. Tube	Bakelite Grade XX	S-5692
11	52	.005"x2"x6"Lg. Insulation	Mica Folium	A-5533
12	13	.013"x2"x6"Lg. Insulation	Fish Paper	.....
13	290 ft.	No. 12 B. & S. Ga. (.0808") Bandwire (Tinned)	Non-Magnetic Steel	G-147972
14	1	1/16"x1"x4"Ft. Lg. Strip (Cut to suit for Clips)	Terne Plate Tinned Steel	.....

Item	Req'd.	SIZE AND NAME	Mat.	Drg. No.
15	65 yds.	Glass Cord No. 305	.....	G-48731
16	4	.010"x2 1/16"x30"Lg. Insulation	Flex. Mica	A-3218
17	10 yds.	.005"x¾" Wide Insulation half-lapped	Glass Tape	A-6114
18	1	20¼"I.D.x21½"O.D.x2 1/16"Lg. Insulation Tube Pt. No. 2	.....	G-163185
19	30	⅜"x1½"Lg. Hex. Hd. Tap Bolt	Steel	
20	10	Double Lock Washer No. 9	Cad. Plate	S-6142
21	20	Insulating Shield No. 3	.....	G-160272
22	20	Insulating Shield No. 4	.....	G-162916
23	2	¼"x1¼"Lg. Sq. Hd. Cup Pt. Set Screw	.....	G-162916
24	2	¼" S.F. Hex. Nut	Steel	
25	4	⅜"x⅞"Lg. Fl. Hd. Cap Screw	Cad. Plate	S-5055
26	18	⅜"x¾" Lg. Hex. Hd. Tap Bolt	Steel	S-6143
27	40	⅜"x2" Lg. Hex. Hd. Tap Bolt	Cad. Plate	S-6188
28	4	Brush Yoke Clamp	Steel	S-6142
29	As Req'd.	Asbestos Putty No. 26	Cad. Plate	S-6142
30	2	⅜"x1¾" Lg. Hex. Hd. Tap Bolt	.....	G-163178
31	15	½"x1½" Lg. Hex. Hd. Tap Bolt	.....	A-2873
32	15	½" Lockwasher Pt. No. 2	Steel	
33	20	¼"x½" Lg. Fillister Hd. Cap Screw	Cad. Plate	S-6142
34	20	¼"Lockwasher	Steel	G-139068
35	10	⅜"Lockwasher	Cad. Plate	S-5038
36	5	Armature Key Pt. No. 15	Steel	
37	52	.005"x2⅜"x6"Lg. Insulation	Cad. Plate	S-6162
38	13	.013"x2⅜"x6"Lg. Insulation	.....	S-5162
				H-156663
			Mica Folium	A-5533
			Fish Paper	.....

NOTES:

I. SPECIAL BANDING INFORMATION
1. TEMPORARY BANDING AS PER ITEM 'A' OF DRG. NO. G-118098
2. INSULATION UNDER BANDS-(4) LAYERS OF ½ LAPPED-ITEM NO.11 NEXT TO COIL. THEN APPLY (1) LAYER OF ½ LAPPED-ITEM NO.12 NEXT TO BAND.
3. BANDWIRE CLIPS AS PER ITEM 'D' OF DRG. NO. G-118098 (SPACED ¼ OF CIRCUM.)
4. BANDS TO HAVE DIP AS PER ITEM 'F' OF DRG NO. G-118098.

II. INSULATE WITH (2) LAYERS ITEM NO.15, AND (1) LAYER OF ITEM NO.17-HALF-LAPPED.

III. PAINT INSIDE OF COMMUTATOR, AND ITEM 18 IS ON OUTSIDE WITH (2) COATS OF G.E. RED GLYPTOL® 1201

IV. TAPE COIL SUPPORT WITH (1) LAYER OF ½ LAPPED-ITEM NO.8. THEN APPLY COIL SUPPORT PACKING ITEM NO.4. TAPE PACKING TO COIL SUPPORT WITH SECOND LAYER OF ½ LAPPED-ITEM NO.8. PAINT EACH LAYER OF TAPE WITH ONE HEAVY COAT OF SPECIAL HIGH TEMP. BAKING VARNISH.

V. PACK AS REQUIRED WITH ITEM NO.29, AND SOLDER WITH PURE TIN OR EQUAL.

VI. TO OBTAIN DIP IN BAND, BUILD UP AS REQUIRED WITH ITEM NO.4, TAPE DOWN WITH (1) LAYER OF HALF-LAPPED-ITEM NO.8. PAINT WITH (2) COATS OF SPECIAL HIGH TEMP. BAKING VARNISH.

VII. TREAT ARMATURE AND FIELD AS PER A-8072

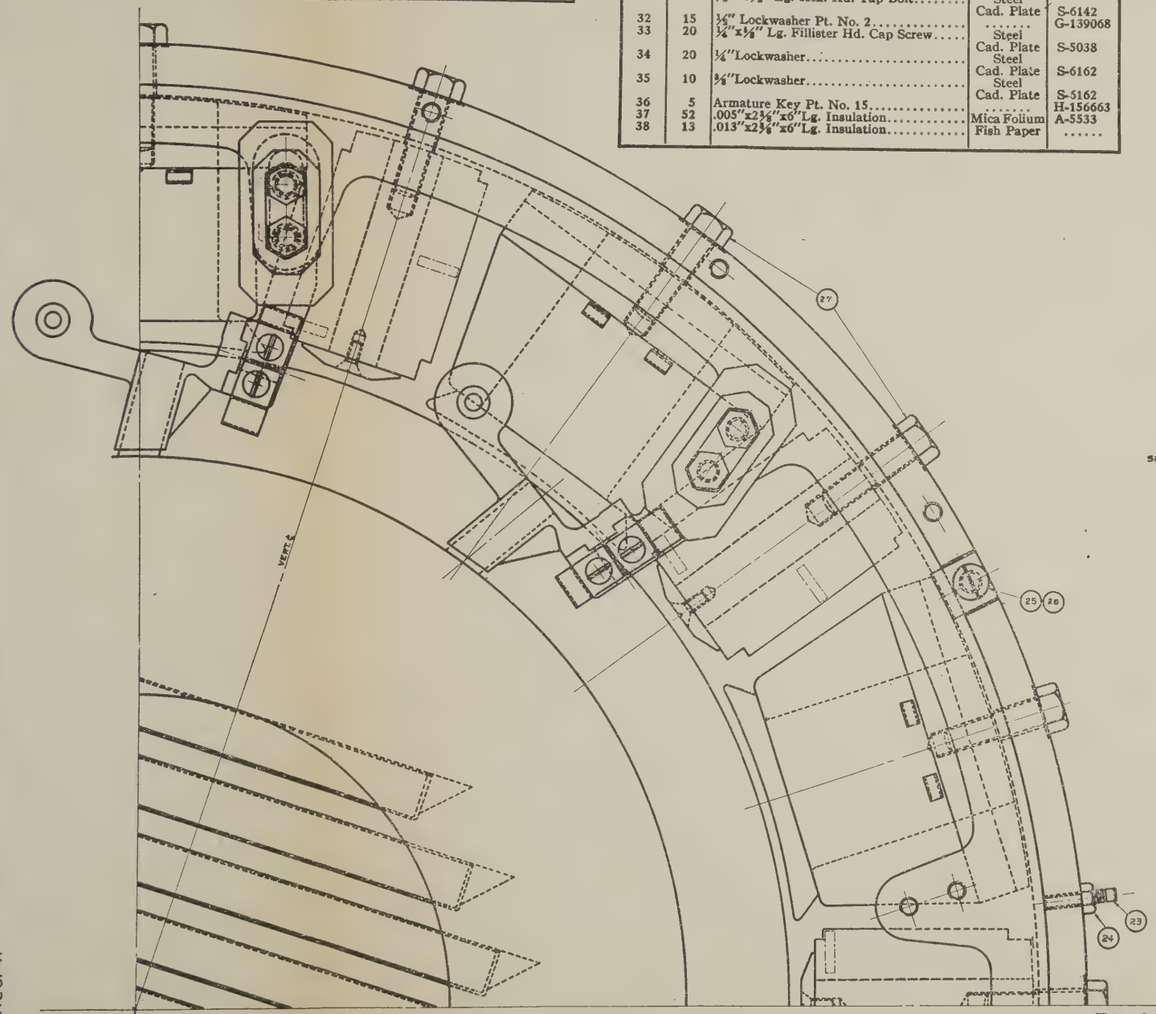
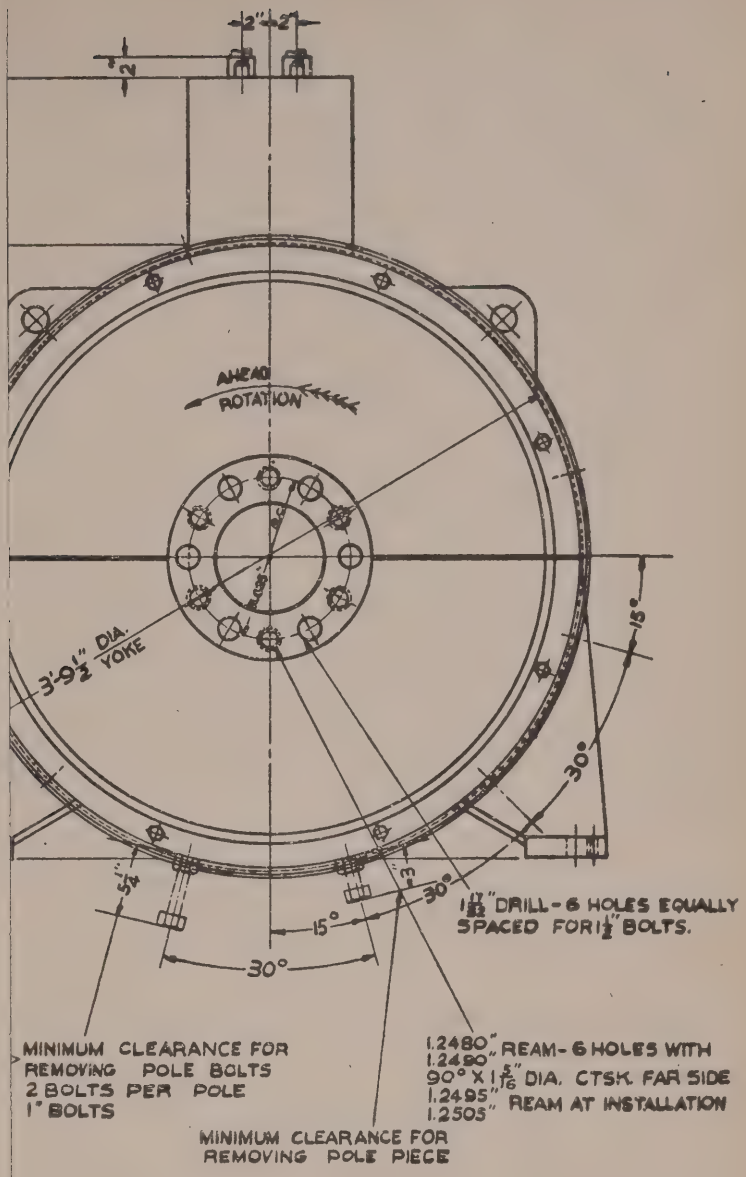


Fig. 26W
Exciter Assembly

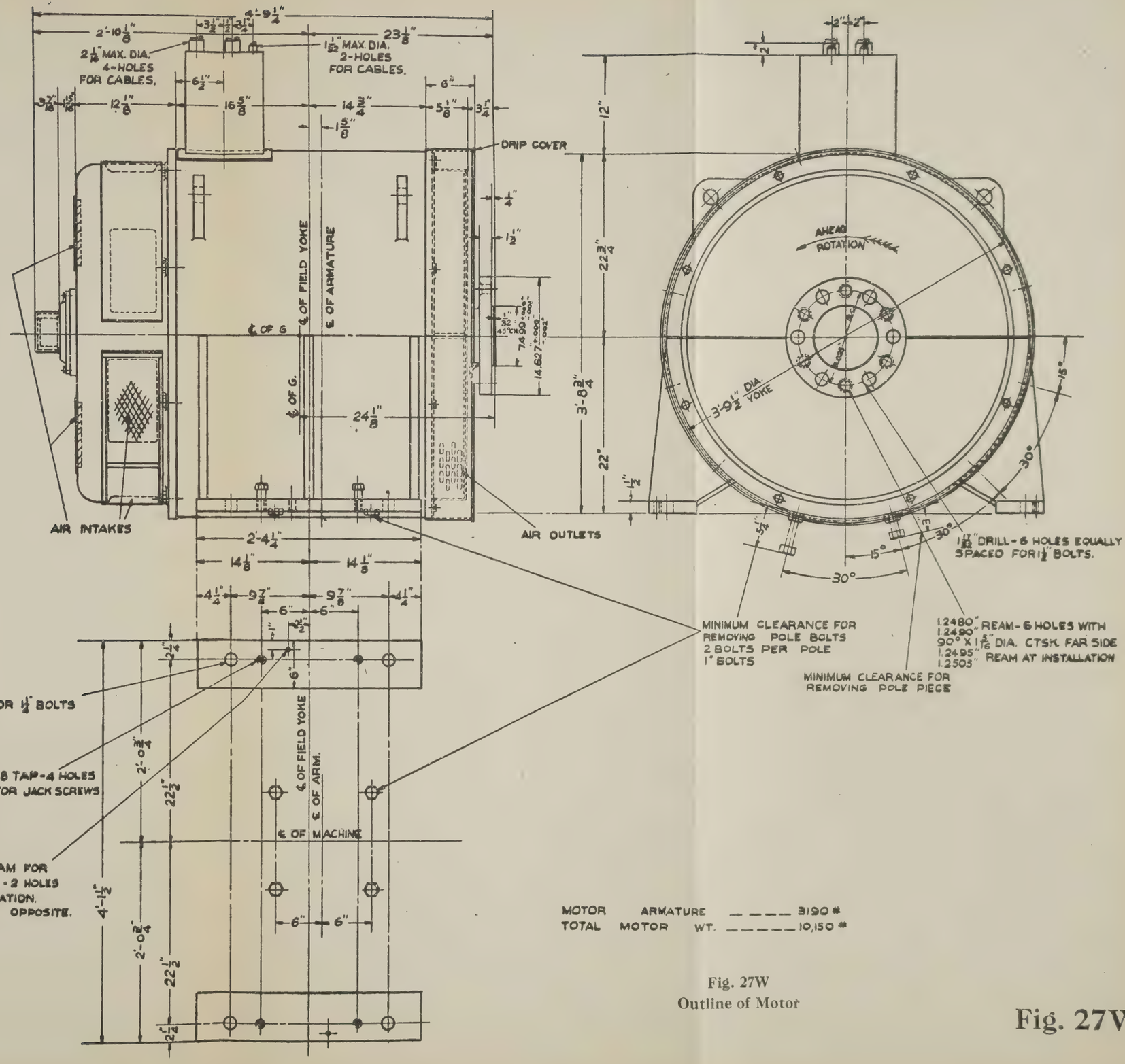
Fig. 26W



)E _____ 3190 #
WT. _____ 10,150 #

Fig. 27W
tline of Motor

Fig. 27W



MOTOR ARMATURE ———— 3190 #
TOTAL MOTOR WT. ———— 10,150 #

Fig. 27W
Outline of Motor

Fig. 27W

PROPULSION AND AUXILIARY CONTROL

PURPOSE AND GENERAL DESCRIPTION

The control system and the apparatus comprising it has been developed to provide a mechanically and electrically simple and compact method of controlling diesel-electrically driven vessels. The system provides means for supplying the power for the two propulsion motors from either one or two generators and also provides means for starting the engines by using the generators as motors and connecting them to the starting battery. The starting, accelerating and reversing of the propeller can be controlled from one of two places—the engine room or the pilot house. Provision is also made for the protection of the propulsion equipment against excessive currents during regular maneuvering as well as possible short circuits in the propulsion system. A manually operated motor field controller permits adjustment of the field current of the motors to suit load conditions.

The purpose of the Auxiliary power control is to provide a means of supplying constant voltage, 125 volt direct current for the control system, propulsion generator and motor field excitation, battery charging and auxiliary motors and lighting. Protection is provided against current reversal in the main feeder circuit and overloads on the auxiliary power sources of supply. The control system includes equipment for charging the 64 volt engine starting battery from a 125 volt source.

Meters and indicating lamps serve to keep the engine room operator informed, at all times, of conditions in all principal circuits. Necessary meters and indicating lamps for propulsion control are also provided in the pilot house.

OPERATION OF PROPULSION CONTROL

Principle of Operation

The propulsion system consists of two motors and two generators that are connected in series in what may be called the "propulsion loop." Each generator has provided a two-position drum type switch—DS-S for the starboard generator and DS-P for the port generator. The two positions for each drum switch, as marked on their escutcheon plates on their respective cut-out switch cabinets, are "Propulsion" and "By-pass." To cut out a generator or cut in a generator the speed controller (engine room or pilot house) must always first be returned to its "Off" position so that motor and generator excitation can be restored after a generator has been removed from or restored to the propulsion loop.

Control of the propulsion motor speed, and consequently the propeller speed, both "ahead" and "astern" is accomplished by changing the intensity and polarity of the generator field current and by changing the speed of the engines. The speed controller, in the engine room control stand, consists of three distinct units. The transmitter for the engine governor receivers, the generator field controller and the interlock contacts. The generator field controller is of the potentiometer type. The governor operation, through the transmitter unit, is by means of an electrical torque motor positioning system acting on all engines simultaneously. No reversing of the engines is required for reversing the propeller. Remote control operation is also accomplished by an electrical torque motor positioning system, the transmitter in the pilot house control stand acting on the main receiver in the engine room control stand. For a given motor field setting, the motor speeds will always correspond directly to the value of the generator voltages. When the generator fields are reversed, the generator polarities reverse and hence the torques of the motors reverse, requiring no interruptions of the power circuit to the motors for any desired speed or direction of rotation.

The two propulsion motor fields are supplied from either self-excited constant voltage exciter. Both motor fields are connected to a single manually operated motor field controller which varies the current in both fields simultaneously. When the motors become heavily loaded, they will tend to draw excessive currents causing possible injury to the electrical machines as well as overloading of the engines. In order to avoid reducing engine speed, and thus its power capacity, the speed of the motors must be reduced independently by means of the motor field its power capacity, the motor speeds must be reduced independently by means of the motor field controller, that is, when the vessel is towing a heavy load the motors may be operated at reduced speed but at full voltage and full engine speed by increasing their field current to a value which will allow maximum armature current without overload.

During rapid acceleration or reversing, it is possible for the motors to tend to take excessive currents momentarily. To offset this condition, a current limiting device is connected in the propulsion loop and is so set that when the current reaches approximately 125% of full load value, the generator field current is immediately and automatically regulated to prevent the propulsion loop current from rising further. The operation of the current limiting device is a cycling operation and will continue as long as the factors causing the excessive current condition are present.

An instantaneous type short circuit protective relay, set to operate at approximately 300% of full load current, acts to remove the generator and motor field excitation, by means of the main field contactor, in the event of conditions arising which may be outside the control of the current limiting device. The field contactor is reclosed automatically when the speed controller is returned to the "Off" position.

OPERATION

Before setting up for propulsion operation make certain that the switches and controls on the following control units are in the positions specified:

Pilot House Control Stand: The speed control handle should be in its "Off" position.

Engine Room Control Stand: The speed control handle should be in the "Off" position and the motor field controller should be in the "Maximum Field" position. The field cut-out switch, below the selector switch, and the governor control cut-out switch, below the voltmeter switch, should both be in their "Open" position. It is also desirable to have the selector switch in the "Manual Control" prior to setting up for propulsion.

Port and Starboard Generator Cut-Out Switch Cabinets: The drum type generator cut-out switches—one in each cabinet—should both be in their "By-pass" position.

Setting Up For Propulsion

Before starting up the main propulsion engines, the exciter to be used for supplying power to the excitation and control bus should be selected as explained under "Operation of Auxiliary Control—Operation—Supplying Excitation and Control Bus Power." If neither auxiliary generator is to supply the main ship's service bus, the controls for the remaining exciter should also be set up to supply the main ship's service bus from this exciter as explained under "Operation of Auxiliary Control—Operation—Supplying Main Ship's Service Bus—Using an Exciter."

For propulsion operation the engines should now be started and running at idling speed.

Note: If one of the exciters is to supply the main ship's service bus, the engine corresponding to that exciter should be started first and then the voltmeter switch on the exciter control panel should be thrown to the proper exciter position immediately after the corresponding engine comes up to idling speed in order to check that the voltage of this exciter is at its proper value. Following this, set up the engine starting battery charging control as explained under "Operation of Auxiliary Control—Operation—Engine Starting Battery Charging" and then close the main ship's service bus control switch as explained under "Operation of Auxiliary Control—Operation—Supplying Main Ship's Service Bus—Using an Exciter." Thus, a power supply is available for charging the engine starting battery immediately after starting the first engine and before starting the second engine.

Each engine is started by pressing the individual engine starting push button switch mounted on the corresponding generator cut-out switch cabinet. The engine starts due to the generator being used as a motor, and when the engine starts to fire the push button may be released. Both engines cannot be started simultaneously—they must be started one at a time since the starting contactors are electrically interlocked. When an engine starting push button is pressed, the blue indicating light on the engine room control stand will be "On" to indicate that a starting contactor is closed. When the engine, corresponding to the exciter being used for excitation and control supply, comes up to idling speed, the voltmeter switch on the exciter control panel should be thrown to the proper exciter position to check that the excitation and control bus voltage is at its proper value.

The next step is to throw the port and starboard generator cut-out switches, in the respective generator cut-out switch cabinets, to their "Propulsion" position. In order to move either one of these cut-out switches it is first necessary to turn its release knob. With the release knob held in the release

position the switch is free and can be thrown to its "Propulsion" position. Releasing the release knob then latches the switch in the position for propulsion operation. The throwing of a generator cut-out switch to its "Propulsion" position causes closing of the corresponding generator field contactor.

The governor control cut-out switch, mounted on the engine room control stand below the voltmeter switch, should now be closed to energize the transmitter, in the engine room control stand, and the two engine governor receivers.

Finally, the field cut-out switch, also on the engine room control stand and mounted below the selector switch, should be closed to energize the main field contactor coil. The closing of the main field contactor, through the energizing of its operating coil, will be indicated by the red indicating lights being "on" on the engine room control stand and on the pilot house meter cabinet. The closing of the main field contactor completes the circuit of the motor fields and energizes the generator field controller.

Propulsion Operation—Engine Room Control

The selector switch, mounted on the engine room control stand directly below the speed control handwheel, should be in its "Manual Control" position shown on its escutcheon plate.

To operate in the "ahead" direction, the speed controller handwheel, on the engine room control stand, is turned at a moderate rate in the direction marked "Ahead" on its escutcheon plate until the desired speed is obtained as indicated by the propeller r.p.m. indicator on the engine room control stand. In increasing speed from zero speed to full speed the current of the generator fields is first increased to its maximum value and then the speed of the engines is increased from idling speed to full speed, that is, movement of the speed controller handwheel causes increased current in the generator fields until the 50% speed position is reached, and at this position, the generator field currents reach their maximum value. Movement of the speed controller handwleel beyond the 50% speed position causes the engines to increase in speed in accordance with the positions of the handwheel.

Note: The procedure of operation given in the preceding paragraph will result in maximum output of the engines at any speed of the propeller provided the motor field controller has been set for the particular load condition when operating with both generators. Therefore, during trial of the vessel, the proper settings of the motor field controller should be determined for various conditions of load. To determine the proper setting of the motor field controller under a free-running condition when using both generators, the motor field controller should be in the "Maximum Field" position, as previously mentioned, and the speed controller handwheel then moved to the full speed ahead position for rated voltage and speed of the generators. The motor field controller should next be adjusted until the current in the propulsion loop circuit reaches normal rated value. The motor field controller should require no further setting unless the number of generators in service is changed or the load conditions change. To determine the proper setting of the motor field controller for just one generator under a free-running condition or for other conditions of load when using one or two generators, the procedure is the same as explained for the free-running condition with two generators, that is, with rated voltage and speed of one or both generators under any load condition, the motor field controller should be adjusted to limit the propulsion loop current to the normal rated value. It should be remembered that, when it is desired to cut in a generator (as explained under "Cutting in a Generator") after operating with just one generator, the motor field controller should first be moved to the position previously determined for operation with two generators under the same particular load condition in order to strengthen the fields of the motors sufficiently to prevent an overcurrent condition when the speed is again increased, by means of the speed controller, after the second generator is cut in.

Reducing propeller speed under any load conditions is accomplished solely by reversing the movement of the speed controller handwheel from full speed ahead toward the "Off" position until the desired speed is reached. Zero generator voltage, and consequently zero speed, is reached when the handwheel is returned to the "Off" position.

For rotating the propeller in the "astern" direction, the speed controller handwheel is turned in the direction marked "Astern" on its escutcheon plate. In "astern" operation the direction of the current

in the generator fields is reversed from that for "ahead" operation.

Current Limiting. Although no harm will be done by moving the speed controller handwheel extremely fast in the "increase speed" or "decrease speed" direction, either "Ahead" or "Astern," nothing will be gained by such operation since the current limiting device (mentioned under "Principle of Operation" and the operation of which is described more fully under "Circuit Description of Operation") will come into operation. The white indicating light on the engine room control stand will flash "on" and "off" whenever the current limiting device is caused to operate since the operation of this device is a cycling operation.

If it is attempted to obtain full propeller speed under heavy towing loads, an overload condition will be obtained causing the current limiting device to operate and the white indicating light to flash. Should the flashes last more than a few minutes, the motor field controller handwheel should be turned in the decrease speed direction, thus increasing the motor field current and consequently the motor torque. It is pointed out here that this lamp should not be solely depended upon to indicate when the motor field controller should be operated, because indications will not be given until an overload condition has been reached, and if the current limiting device is cycling at a high speed, the flashes of the indicating light may not be discernable. The ammeter should be observed to see that the current does not reach an overload value during prolonged heavy towing.

Short Circuit Protection. Supplementing the current limiting device is an instantaneous short circuit relay which when caused to operate will in turn remove the generator and motor field excitation. Removing of the excitation is indicated by red indicating lights being "off" on the engine room control stand and the pilot house meter cabinet.

The short circuit protective relay resets itself automatically when the current in the propulsion loop is reduced due to the removal of the machine excitation. To place the propulsion system in operation again, it will only be necessary to return the speed controller handwheel to the "Off" position and then again proceed with the propulsion operation.

Propulsion Operation—Remote Control

The selector switch, mounted on the engine room control stand directly below the speed controller handwheel, should be thrown to its "Remote Control" position, shown on its escutcheon plate, to energize the remote control positioning system. Care must always be taken when operating this switch to see that the handle of the pilot house control stand is always in the "Off" position, otherwise the remote control positioning system will immediately tend to bring the speed controller of the engine room control stand to whichever position the pilot house control stand handle dictates.

To operate in the "ahead" direction, the handle of the pilot house control stand is moved at a moderate rate in the direction marked "Ahead" on the escutcheon plate until the desired speed is obtained as indicated by the propeller r.p.m. indicator in the pilot house meter cabinet. In operating from a remote control station, the remote control positioning system operates the speed controller in the engine room control stand to first increase the currents of the generator fields to their maximum value and then increase the speed of the engines from idling speed to full speed, whereas, during engine room control the speed controller in the engine room control stand is operated by hand.

For rotating the propeller in the "astern" direction, the handle of the pilot house control stand is moved in the direction marked "Astern" on the escutcheon plate. In "astern" operation, the speed controller causes the current in the generator fields to be reversed from that for "ahead" operation.

Current limiting operation and short circuit protection is the same as explained under "Engine Room Control" except that after the short circuit relay has operated the propulsion system is placed in operation again by returning the handle of the pilot house control stand to the "Off" position in lieu of returning the speed controller handwheel, on the engine room control stand, to its "Off" position.

Removing a Generator From the Propulsion Loop

To remove a generator from the propulsion loop, either the speed controller handwheel or the handle of the pilot house control stand—depending upon which control is being used—should first be returned to its "Off" position.

The next step is to throw the generator cut-out switch, corresponding to the generator to be removed, to its "By-pass" position shown on its

escutcheon plate. In order to move the generator cut-out switch it is again first necessary to turn its release knob. With the release knob held in the release position the switch is free and can be thrown to its "By-pass" position. Releasing the release knob then latches the switch in its "By-pass" position. When a generator cut-out switch is in the "By-pass" position the corresponding generator field contactor is open.

The engine, corresponding to the generator removed from the propulsion loop, can now be stopped by the means provided. However, if the exciter, of the engine-generator set being shut down, is supplying excitation and control power, it will first be necessary to transfer the excitation and control bus to the exciter of the other engine-generator set by means of the exciter selector switch on the exciter control panel as explained under "Operation of Auxiliary Control—Operation—Supplying Excitation and Control Bus Power."

When operating with only one generator, the voltage across the propulsion motors will be one-half of the value obtained when two generators were used, and as a result, the motor field controller, on the engine room control stand, must be turned in the "Increase Speed" direction. The position of the motor field controller will be determined by the propulsion loop ammeter reading so as to avoid overloading of the generator and engine. It will be found that when only one engine-generator set is operated, the motors must be run at approximately 80% of full speed in order to obtain full output of the single engine.

Cutting In a Generator

To cut in a generator, when the propulsion system is in operation with one generator, it is first necessary to return either the speed controller handwheel or the handle of the pilot house control stand to the "Off" position, depending upon which control is being used. Also, set the motor field controller to the point previously determined for two generators for the particular condition as was described in "Note" under "Operation—Propulsion Operation—Engine Room Control" in order to strengthen the motors sufficiently to prevent an overcurrent condition when the second generator is cut in.

The engine is then started by pressing the individual engine starting push button switch mounted on the corresponding generator cut-out switch cabinet and when the engine starts to fire the push button may be released. The blue indicating light on the engine room control stand will be "on" when the starting contactor is closed.

The next step is to throw the generator cut-out switch to its "Propulsion" position. In order to move the generator cut-out switch it will be necessary to turn and hold the release knob in the release position to free the switch for movement, and after the switch has been thrown the release knob can be released. The generator field contactor will be closed when the generator cut-out switch is in its "Propulsion" position.

Operation from the desired control station now causes both generators to supply power to the propulsion loop and, if necessary, final load adjustments should be made with the motor field controller. See "Note" under "Operation—Propulsion Operation—Engine Room Control."

Shutting Down the Propulsion System

To shut down the propulsion system the speed controller handwheel on the engine room control stand or the handle of the pilot house control stand —depending upon which station is being used— should first be returned to the "Off" position. If the remote control station has been used, it is desirable to throw the selector switch, mounted on the engine room control stand directly below the speed controller handwheel, to its "Manual Control" position after the handle of the pilot house control stand has been returned to its "Off" position.

Additional operations to shut down the propulsion system are as follows: (1) Open the field cut-out switch and the governor control cut-out switch, both on the engine room control stand. (2) Throw both port and starboard generator cut-out switches, in the respective generator cut-out switch cabinets, to their "By-pass" position. In order to move either one of these cut-out switches it will again first be necessary to turn and hold its release knob in the release position to free the switch for movement, and after the switch has been thrown the release knob can be released. (3) The controls for the exciter having supplied the excitation and control bus should be returned to their shut-down position as explained under "Operation of Auxiliary Control — Operation — Supplying Excitation and Control Bus Power." If the other exciter was used to supply the main ship's service bus, the main ship's service bus load should be transferred to an

auxiliary generator and then the controls for that exciter should also be returned to their shut-down position as explained under "Operation of Auxiliary Control—Operation—Supplying Main Ship's Service Bus—Using an Exciter." (4) Both port and starboard engines can now be stopped.

CIRCUIT DESCRIPTION OF OPERATION

See Fig. 24X

Setting Up for Propulsion

For propulsion operation the exciter—port or starboard—to be used for excitation and control bus supply should first be selected. The circuit description of operation involved is explained under "Operation of Auxiliary Control—Circuit Description of Operation—Supplying Excitation and Control Bus Power." If the other exciter is to be used for supplying the main ship's service bus, the circuit description of operation involved is explained under "Operation of Auxiliary Control—Circuit Description of Operation—Supplying Main Ship's Service Bus—Using an Exciter."

To start the port engine, the starting push button PB-P, for the port engine, is pressed. This completes a circuit from the positive starting battery bus SBP through the engine starting push button PB-P, through the normally closed auxiliary contacts of the port generator cut-out switch DS-P, through the normally closed auxiliary contacts S2-S of the starboard engine starting contactor and through the coils of the two port engine starting contactors S1-P and S2-P to the negative starting battery bus SBN. (The auxiliary DS-P contacts in this circuit are closed when the port generator cut-out switch DS-P is in its "By-pass" position.) Energizing of the engine starting contactor coils S1-P and S2-P causes closing of the main contacts S1-P and S2-P, thus completing a circuit from the positive starting battery bus SBP through main contacts S1-P, through the armature and starting field winding of the port generator and through main contacts S2-P to the negative starting battery bus SBN. Consequently, the port generator acts as a motor to start the port engine. At the time main contacts S2-P close, a set of auxiliary normally closed S2-P contacts open in the coil circuit of starboard engine starting contactors S1-S and S2-S, so that only one engine can be started at a time. Also, at the time main contacts S1-P close, a set of auxiliary normally closed S1-P contacts open in the coil circuit of voltage relay TVR of the engine starting battery charging equipment, thus causing this relay to drop out and open its contacts. The circuit description of the resultant operation is explained under "Operation of Auxiliary Control—Circuit Description of Operation—Engine Starting Battery Charging." Energizing of coils S1-P and S2-P also causes normally open auxiliary contacts S1-P and S2-P to close in the circuit of the blue indicating light, and thus this light will be "On" to indicate that the engine starting contactors for the port engine are closed. After the engine has started and push button PB-P is released, the main and auxiliary contacts, of the engine starting contactor, will return to their normal position and the blue indicating light on the engine room control stand will again be "Off."

The circuit description of operation for starting the starboard engine is the same as that given for starting the port engine except that all contact and coil designations have the suffix S instead of P.

After the engines have been started, the port and starboard generator cut-out switches, DS-P and DS-S respectively, should be thrown to their "Propulsion" position, thus causing the main contacts DS-P and DS-S to connect the port and starboard generator into the propulsion loop. Before being able to throw either generator cut-out switch to its "Propulsion" position, the release knob, beside the main lever of the switch, must be turned. This causes corresponding normally closed DS-P or DS-S latch contacts to open in the coil circuit of the main field contactor F. After the switch is thrown and the release knob is released, the switch is latched in the "Propulsion' position and these latch contacts close again. Thus, the excitation circuit of the generators and motors, through the action of the main field contactor F, is always interrupted when a generator cut-out switch is operated. Throwing these generator cut-out switches DS-P and DS-S to their "Propulsion" position, closes the corresponding normally open auxiliary contacts DS-P and DS-S in the coil circuit of the respective generator field contactor GF-P and GF-S, thus completing circuits from the positive control bus through the auxiliary contacts DS-P or DS-S of the switch being thrown, through the corresponding generator field contactor coil GF-P or GF-S to the negative control bus. The energizing of these generator field contactor coils causes closing of the respective gen-

erator field contacts GF-P and GF-S, thus connecting the fields of the port and starboard generators to the generator field control unit GFC of the speed controller. However, the fields of the generators will not be energized since the generator field control unit GFC is not yet energized and since the speed controller is in the "Off" position. When a generator cut-out switch is thrown to its "Propulsion" position, a set of normally closed auxiliary contacts open in the coil circuit of the corresponding engine starting contactors, thus making it imperative that a generator cut-out be in its "By-pass" position when attempting to start the corresponding engine.

The governor control cut-out switch SG should now be closed, and thus the governor transmitter unit T2, of the speed controller, and the port and starboard engine governor receivers, R-P and R-S respectively, are energized from the positive and negative control bus.

Finally, the field cut-out switch SW1 should be closed. This completes a circuit from the positive control bus through the normally closed DS-P latch contacts, through the normally closed DS-S latch contacts, through the normally closed short circuit relay contacts SC, through the field cut-out switch SW1, through the speed controller interlock contacts CX (closed in the "Off" position) and through the coil of the main field contactor F to the negative control bus, thus closing the F contactor. The closing of the F contactor energizes the port and starboard motor fields through the motor field controller RH1. Also, the resistors of the generator field control unit GFC are now energized but the fields of the generators will not be energized since the speed controller is in the "Off" position. In addition, the red lights, on the engine room control stand and the pilot house meter cabinet, are energized by the closing of the F contactor. Auxiliary normally open F contacts are also closed to maintain the circuit of the F contactor coil after the CS contacts are opened due to speed control operation.

Propulsion Operation—Engine Room Control

The selector switch SS should be in the "Manual Control" position and its contacts will then be open as shown on schematic diagram Fig. 24X and as a result the remote control positioning system is not energized.

Movement of the speed controller handwheel in the "Ahead" direction cuts resistance steps out of the generator field control unit GFC due to the rotation of the brushes, and as a result, current will begin to flow in the fields of the port and starboard generators as explained more generally on page X-28, Fig. 9X—"Generator Field Controller." Consequently, a voltage is built up across the generator armature and current flows in the propulsion loop. Further movement of the handwheel increases the generator field current until full generator field current is obtained at 50% travel of the handwheel while the engine speed is held constant at idling (50%) speed. Since full generator field current at one-half engine speed results in one-half generator voltage, the motors will be running at one-half maximum speed as set by the motor field controller RH1.

Movement of the speed controller handwheel beyond the one-half speed position causes the generator field current to remain constant at its maximum value and causes the governor transmitter unit T2, of the speed controller, to start to rotate the engine governor receivers R-P and R-S, thus increasing the speed of the engines until full engine speed is reached at full travel of the handwheel. For a general description of this operation refer to Fig. 11X—"Governor Positioning System." (It should be noted that the number of steps given in the bulletin explanation for the transmitter is not necessarily the same as the number of steps for transmitter T2. For the actual number of steps refer to Fig. 29X—"Wiring Diagram of Governor Transmitter.") Consequently, with maximum field current and full engine speed, full voltage will be generated, resulting in full propulsion motor speed corresponding to the setting of the motor field controller RH1.

Since rated generator, speed and voltage is obtained with the speed controller in the full speed position, full propeller speed is obtained by adjusting the motor field current, by means of the motor field controller RH1, until the propulsion loop ammeter indicates full rated current. Further adjustment of motor field current will only be necessary if the load conditions change or if propulsion operation is performed with only one generator.

Reducing propeller speed is accomplished by reversing the movement of the speed controller handwheel from full speed ahead toward the "Off" position. Zero generator voltage, and consequently zero speed, is reached when the handwheel is returned to the "Off" position.

Moving the speed controller handwheel in the "Astern" direction reverses the direction of the current from the generator field control unit GFC to the fields of the generators. This in turn causes a reversal of generator voltages, resulting in reversed motor rotation.

Current Limiting. If an attempt is made to accelerate too fast, in either the "ahead" or "astern" direction, the current limiting relay CLD, in the propulsion loop, closes its contacts at greater than 125% of full load current. This completes a circuit from the positive control bus through the current limiting relay contacts CLD and through the coil of generator field reducing contactor CLDX to the negative control bus. The energizing of coil CLDX causes opening of the normally closed CLDX contacts in parallel with the resistor between each generator field and the generator field control unit GFC, thus inserting resistance in the field circuits of the generators to reduce generator voltage and thus loop current. When the loop current diminishes sufficiently, relay CLD again opens its contacts to restore contacts CLDX to their normal position. If the conditions causing excessive loop current still exist, the cycle is repeated until normal conditions are restored. Whenever the CLD relay operates, the white indicating light will be energized since auxiliary CLDX contacts close in this light circuit whenever the coil of the generator field weakening contactor CLDX is energized.

If the current limiting device relay should operate after acceleration has been completed, an overload condition exists and it should be corrected by increasing the motor field strength.

Short Circuit Protection. If the current in the propulsion loop should reach approximately 300% of rated full load current, the instantaneous short circuit relay SC is caused to open its contacts, thus interrupting the coil circuit of the main field contactor F which in turn opens the F contactor. As a result, the excitation is removed from the port and starboard motor fields, and in addition, the excitation is removed from the port and starboard generator fields due to the circuit of the generator field control unit GFC being interrupted by the F contactor. The opening of the F contactor also de-energizes the two red indicating lights. Auxiliary F contacts in the F contactor coil circuit are also opened to prevent reclosing of the F contactor coil circuit after the short circuit relay resets itself.

The de-energizing of the generator fields reduces the propulsion loop current to zero and the short circuit relay resets itself automatically, that is, its normally closed contacts again close in the coil circuit of the F contactor. However, the F contactor coil will not become energized since auxiliary F contacts and the CX interlock contacts are open. Therefore, to re-establish excitation for the generators and motors, it is necessary to move the speed controller handwheel to the "Off" position. This closes the CX interlock contacts to energize the F contactor coil from the control bus, thus again causing the F contactor to close.

Propulsion Operation—Remote Control

The selector switch SS should be thrown to the "Remote Control" position, thus closing the normally open SS contacts shown on schematic diagram Fig. 24X, and as a result the remote control positioning system, consisting of the transmitter T1 in the starboard pilot house control stand and receiver R1 in the engine room control stand, is energized from the positive and negative control bus.

Movement of the control stand handle in the "Ahead" direction causes the remote control positioning system transmitter T1 to start to rotate receiver R1. For a general description of this operation refer to Fig. 12X—"Main Positioning System." (It should be noted that the number of steps given in the bulletin explanation for the transmitter is not necessarily the same as the number of steps for tramsmitter T1. For the actual number of steps refer to Fig. 30X—"Wiring Diagram of Pilot House Transmitter.") Receiver R1 in turn performs the same function that turning the speed controller handwheel performed as described under "Propulsion Operation—Engine Room Control," that is, receiver R1 first cuts resistance steps out of the generator field control unit GF2 until full generator field current is obtained at 50% travel of the control stand handle, and further movement of the handle causes receiver R1 to rotate the governor transmitter unit T2, which in turn rotates the engine governor receivers R-P and R-S to increase the speed of the engines.

Reducing propeller speed is accomplished by reversing the movement of the pilot house control stand handle from full speed ahead toward the "Off" position.

Moving the control stand handle in the "Astern" direction reverses the direction of rotation of receiver R1, thus reversing the current in the generator field and consequently reversing the potential of the generators which results in reversed motor rotation. The engine governor receivers R-P and R-S rotate in the same direction as for "ahead" operation to increase engine speed.

For current limiting and short circuit protection refer to corresponding sub-sections in sub-section "Propulsion Operation—Engine Room Control." It is to be noted that, to re-establish excitation for the generators and motors after the short circuit relay SC has operated during remote control, it is necessary to return the handle of the pilot house control stand to its "Off" position in lieu of returning the speed control handwheel, on the engine room control stand, to its "Off" position.

Removing a Generator From the Propulsion Loop

To remove a generator from the propulsion loop, either the speed controller handwheel or the handle of the pilot house control stand—depending upon which control is being used—should first be returned to its "Off" position, so that no current will flow in the propulsion loop when it is momentarily opened by the removal of a generator and so that motor and generator excitation can be restored after a generator has been removed from the propulsion loop.

Assume that it is desired to remove the port generator from the propulsion loop. Generator cut-out switch DS-P should be thrown to its "By-pass" position, thus causing the main DS-P contacts to be restored to their normal position shown on schematic diagram Fig. 24X. Before being able to throw generator cut-out switch DS-P to its "By-pass" position the release knob, beside the main lever of the switch, must be turned. This causes DS-P latch contacts to open in the coil circuit of the main field contactor F. After the switch is thrown and the release knob is released, the switch is latched in the "By-pass" position and the latch contacts close again to restore excitation to the motors and the remaining generator. Throwing generator cut-out switch DS-P to its "By-pass" position, causes auxiliary DS-P contacts, in the coil circuit of generator field contactor GF-P, to be restored to their normally open position, thus opening GF-P contacts in the field circuit of the port generator. Also, auxiliary DS-P contacts are restored to their normally closed position in the coil circuit of the port engine starting contactors S1-P and S2-P.

If the port exciter is supplying excitation and control power, it will be necessary to transfer the excitation and control bus load to the starboard exciter before shutting down the port engine.

Removing a generator from the propulsion loop decreases the voltage across the motors, thus making it necessary to increase their speed by operating RH1 to cut in resistance in the field circuit of the motors.

If it is desired to remove the starboard generator from the propulsion loop in lieu of the port generator, the circuit description of operation is similar except that it applies to controls for the starboard generator in lieu of the port generator.

Cutting In a Generator

To cut in a generator, when the propulsion system is in operation with one generator, either the speed controller handwheel or the handle of the pilot house control stand—depending upon which control is being used—should again first be returned to its "Off" position, so that no current will flow in the propulsion loop when it is momentarily opened by the cutting in of a generator and so that motor and generator excitation can be restored after the generator has been cut into the propulsion loop. Also, before cutting in a generator, the field strength of the motors should be increased sufficiently by means of RH1, since cutting in a generator doubles the voltage across the motors, and as a result, when the speed controller is moved to the "Full Speed" position obtaining full generator voltage, an overload condition will exist if the motor field strength is not sufficient.

Assume that the propulsion system is operating with the starboard generator only and that it is desired to cut in the port generator. The port engine should first be started by pressing push button PB-P and the circuit description of operation is the same as given for starting the engine under "Setting Up for Propulsion."

The next step is to throw generator cut-out switch DS-P to its "Propulsion" position and the circuit description of this operation is given under "Setting Up for Propulsion."

If the propulsion system is operating with the port generator only and it is desired to cut in the

starboard generator, the circuit description of operation is similar except that it applies to controls for starboard generator in lieu of the port generator.

Shutting Down the Propulsion System

To shut down the propulsion system the speed controller handwheel or the handle of the pilot house control stand—depending upon which control station is being used—should first be returned to the "Off" position. This returns receivers R-P and R-S to their idling speed position due to the rotation of the brushes of the governor transmitter unit T2 and also reduces to zero the excitation of the port and starboard generator by adding resistance steps in the circuit of the generator fields due to the rotation of the brushes of the generator field control unit GFC. If the remote control station has been used, it is desirable to de-energize the remote control positioning system by opening the selector switch SS by throwing it to the "Manual Control" position after the handle of the pilot house control stand has been returned to its "Off" position.

Now open the field cut-out switch SW1, thus de-energizing the coil of the F contactor and causing the F contactor to open. This is indicated, on the engine room control stand and the pilot house meter cabinet, by the red indicating lights being "off." The opening of the F contactor de-energizes the port and starboard motor fields and the generator field control unit GFC. Auxiliary F contacts also open in the coil circuit of the F contactor coil.

The next step is to open the governor control cut-out switch SG to de-energize the port and starboard engine governor receivers, R-P and R-S, and also the governor transmitter unit T2.

The port and starboard generator cut-out switches, DS-P and DS-S respectively, should now be thrown to their "By-pass" position, thus causing the main DS-P and DS-S contacts to be restored to their normal position shown on schematic diagram Fig. 24X. Before being able to throw either generator cut-out switch to its "By-pass" position, the release knob, beside the main lever of the switch, must be turned. This causes corresponding normally closed DS-P and DS-S latch contacts to open in the coil circuit of the main field contactor F. After the switch is thrown and the release knob is released, the switch is latched in the "By-pass" position and these latch contacts close again. Throwing generator cut-out switches DS-P and DS-S to their "By-pass" position, restores the auxiliary DS-P and DS-S contacts, in the coil circuit of the respective generator field contactor GF-P and GF-S, to their normally open position, and as a result, the generator field contacts GF-P and GF-S are opened in the field circuits of the port and starboard generators respectively. Also, auxiliary DS-P and DS-S contacts are restored to their normally closed position in the coil circuit of the corresponding engine starting contactors.

The controls for the exciter, having supplied the excitation, and control bus should be returned to their shut-down position and the circuit description of operation is given under "Operation of Auxiliary Control—Circuit Description of Operation—Supplying Excitation and Control Bus Power," and in the event the other exciter was used to supply the main ship's service bus, the circuit description of operation for returning the controls for this exciter to the shut-down position is as given under "Operation of Auxiliary Control—Circuit Description of Operation—Supplying Main Ship's Service Bus—Using an Exciter."

OPERATION OF AUXILIARY CONTROL

Principle of Operation

The excitation and control bus for propulsion operation is supplied from either the port or starboard exciter. When one of the exciters is connected to the excitation and control bus, the other exciter is available to supply the main ship's service bus. A voltage regulator is located in the field circuit of each exciter so that the voltage of each exciter is held constant irrespective of the speed changes of the propulsion generator driving engines which also drive these exciters. Voltage adjusting rheostats are also provided in each exciter field circuit for adjusting the regulated voltage.

The main ship's service bus serves equipment that is essential to the running of the vessel including the battery charging control for charging the 64 volt propulsion engine starting battery. The main ship's service bus is supplied from either one of the exciters, as mentioned in the preceding paragraph, or from either the 30 kw. or the 60 kw. auxiliary generator each of which is driven by a separate auxiliary diesel engine. A ship's service battery normally "floats" on the main ship's service bus and supplies necessary power only when the main ship's service

bus is not being supplied from an exciter or auxiliary generator.

The supplementary ship's service bus can be supplied only from either the 30 kw. or the 60 kw. auxiliary generator. When power is being supplied to the supplementary ship's service bus, the main ship's service bus must be supplied from either the port or starboard exciter.

The towing motor circuit can be supplied only from the 30 kw. auxiliary generator. When power is being supplied to the towing motor, the supplementary ship's service bus must be supplied from the 60 kw. auxiliary generator.

The connections for supplying the various load circuits from the various sources of supply, as mentioned in the preceding four paragraphs, are obtained by means of three 4-pole double throw knife switches on the exciter control and auxiliary generator control panels and these switches are known as the bus selector switch, auxiliary generator selector switch and exciter selector switch.

Each auxiliary generator is self-excited when used to supply the main or supplementary ship's service bus and each generator field is provided with a field rheostat. When the 30 kw. auxiliary generator is supplying power to the towing motor, its field is then separately excited through the towing motor control and its field rheostat is cut out of its shunt field circuit. The 30 kw. auxiliary generator also has a series field which is "differential" connected when supplying the towing motor and connected "accumulative" when supplying either ship's service bus. This reversing of the series field connections is accomplished by the auxiliary generator selector switch.

Overload protection is provided for each auxiliary generator. Overload protection is also provided for either exciter when it is supplying the main ship's service bus. If the load of the main ship's service bus exceeds 125% of the full load rating of the machine supplying its power, the thermal overload relay for that machine will cause tripping of the main ship's service bus contactor. Likewise, if the load of the supplementary ship's service bus exceeds 125% of the full load rating of the auxiliary generator supplying its power, the thermal overload relay for that auxiliary generator will cause tripping of the supplementary ship's service bus contactor.

A reverse current relay is provided for the main ship's service bus, so that, when the exciter or auxiliary generator supplying the main ship's service bus is shut down without opening the main ship's service bus contactor, the reverse current relay will open the main ship's service bus contactor to prevent the ship's service battery from discharging through the machine which had supplied the main ship's service bus prior to having been shut down. No reverse current protection is provided for the supplementary ship's service bus since there is no battery connected to the supplementary ship's service bus.

OPERATION

When all auxiliary equipment is shut down, the switches and controls on the following control panels are in the positions specified:

Exciter Control Panel: The push-pull type field cut-out switches for the port and starboard exciters should both be in their "open" position. The voltage adjusting rheostats should be in some intermediate position. The exciter selector knife switch should be in the "open" position. The voltmeter and ground detector switches should both be in their "Off" position.

Auxiliary Generator Control Panel: The push-pull type cut-out switches for the main ship's service bus and the supplementary ship's service bus should be in their "open" position. The bus selector knife switch and the auxiliary generator selector knife switch should both be in the "open" position. The field rheostats for both auxiliary generators should be in some intermediate position.

Engine Starting Battery Charging Cabinet. The battery charging cut-out switch toward the left side of the cabinet should be in its "Open" position.

Note: The double-pole disconnect switch on the distribution panel (not furnished) should be open.

Supplying Excitation and Control Bus Power

Setting Up Exciter. The exciter selector knife switch, on the exciter panel, should be thrown to the right if it is desired to use the port exciter or to the left if it is desired to use the starboard exciter to supply excitation and control bus power. If an exciter is to supply the main ship's service bus, the remaining exciter is automatically selected for this purpose through the exciter selector knife switch.

The port or starboard exciter field cut-out switch on the exciter panel—depending upon which exciter

was chosen for excitation and control bus power when the exciter selector knife switch was thrown—should now be pushed in to its "closed" position.

The propulsion engine corresponding to the selected exciter should now be started as explained under "Operation of Propulsion Control—Operation—Setting Up for Propulsion."

Then throw the voltmeter switch, on the exciter panel, to the position corresponding to the exciter selected.

After the engine comes up to idling speed, turn the knob of the corresponding exciter voltage adjusting rheostat until the voltmeter indicates that the control voltage has been established. The operation of the corresponding voltage regulator then maintains a constant voltage irrespective of the speed of the engine during propulsion operation.

Shutting Down Exciter. To shut down the exciter supplying excitation and control bus power, the corresponding exciter field cut-out switch should first be pulled out to its "open" position and then open the exciter selector knife switch.

Supplying Main Ship's Service Bus Using an Exciter

Setting Up Exciter. When using an exciter to supply power to the main ship's service bus, the propulsion system is obviously going to be in operation. Consequently, one of the exciters has been selected to supply power to the excitation and control bus and the remaining exciter is automatically selected to supply power to the main ship's service bus as explained under "Supplying Excitation and Control Bus Power."

The bus selector knife switch should be thrown to the right to set up the circuit from the exciter selector knife switch to the main ship's service bus. When the bus selector knife switch is thrown to the right, another circuit is set up from the auxiliary generator selector knife switch to the supplementary ship's service bus, so that the supplementary ship's service bus can be supplied from an auxiliary generator as explained under "Supplying Supplementary Ship's Service Bus."

The port or starboard exciter field cut-out switch on the exciter panel—depending upon which exciter is to supply the main ship's service bus—should be pushed in to its "closed" position.

The propulsion engine corresponding to the selected exciter should now be started as explained under "Operation of Propulsion Control—Operation—Setting Up for Propulsion."

Then throw the voltmeter switch, on the exciter panel, to the position corresponding to the exciter being used to supply the main ship's service bus.

After the engine comes up to idling speed, turn the knob of the corresponding exciter voltage adjusting rheostat until the voltmeter indicates that the proper main ship's service bus voltage has been established. The operation of the corresponding voltage regulator then maintains a constant voltage irrespective of the speed of the engine during propulsion operation.

The push-pull type main ship's service bus control switch, on the auxiliary generator control panel, should now be pushed in to its "closed" position. The corresponding red indicating light, directly above the main ship's service bus control cut-out switch, will be "on" to indicate that the main contactor for the main ship's service bus is closed.

Overload Protection. In the event the load of the main ship's service bus causes the exciter to become overloaded, a thermal overload relay in the exciter circuit will trip the main contactor for the main ship's service bus as indicated by the red indicating light, above the main ship's service bus control cut-out switch on the auxiliary generator control panel, being "off." To restore operation the overload relay must be manually reset as explained in the description of type TH thermal overload relays found elsewhere in this book.

Shutting Down Exciter. To shut down the exciter supplying the main ship's service bus, the main ship's service bus control switch should be pulled out to its "open" position and then open the exciter field cut-out switch.

Open the bus selector knife switch unless one of the auxiliary generators is supplying the supplementary ship's service bus. Also, open the exciter selector knife switch unless the other exciter is still to be used to supply excitation and control bus power.

Supplying Main Ship's Service Bus Using an Auxiliary Generator

Setting Up Auxiliary Generator. Either auxiliary generator No. 1 (60 kw.) or auxiliary generator No. 2 (30 kw.) may be used to supply the main ship's service bus. The auxiliary generator selector

knife switch, on the auxiliary generator control panel, should then be thrown to the left if it is desired to use auxiliary generator No. 1 or to the right if it is desired to use auxiliary generator No. 2 to supply power to the main ship's service bus. If auxiliary generator No. 1 is to supply the main ship's service bus, the auxiliary generator selector knife switch makes auxiliary generator No. 2 available for supplying power to the towing motor.

The bus selector knife switch should be thrown to the left to set up the circuit from the auxiliary generator selector knife switch to the main ship's service bus.

The diesel engine corresponding to the selected auxiliary generator should now be started. (See Section E.)

Then throw the voltmeter switch, on the exciter panel, to the position corresponding to the auxiliary generator being used to supply the main ship's service bus.

After the engine comes up to speed, turn the knob of the corresponding auxiliary generator field rheostat until the voltmeter indicates that proper main ship's service bus voltage has been established. This voltage should be checked occasionally.

The push-pull type main ship's service bus control switch, on the auxiliary generator control panel, should now be pushed in to its "closed" position. The corresponding red indicating light, directly above the main ship's service bus control cut-out switch, will be "on" to indicate that the main contactor for the main ship's service bus is closed.

Overload Protection. Each auxiliary generator has a thermal overload relay in its armature circuit, so that, in the event the load of the main ship's service bus causes the auxiliary generator supplying the main ship's service bus to become overloaded, the corresponding overload relay will trip the main contactor for the main ship's service bus as indicated by the red indicating light, above the main ship's service bus control cut-out switch on the auxiliary generator control panel, being "off." To restore operation the overload relay must be manually reset as explained in the description of type TH thermal overload relays found elsewhere in this book.

Shutting Down Auxiliary Generator. To shut down the auxiliary generator supplying the main ship's service bus, the main ship's service bus control switch should be pulled out to its "open" position.

Then open the bus selector knife switch. Also, open the auxiliary generator selector knife switch unless auxiliary generator No. 2 is being used to supply power to the towing motor.

Finally, stop the diesel engine by the means provided.

Supplying Main Ship's Service Bus Reverse Current Protection

When an exciter is supplying power to the main ship's service bus and when the engine driving that exciter is shut down without first opening the main ship's service bus control switch, the reverse current relay will automatically trip the main contactor for the main ship's service bus to prevent discharge of the main ship's service battery through the exciter. This same reverse current relay protects against reverse current when an auxiliary generator is supplying the main ship's service bus.

Supplying Supplementary Ship's Service Bus

Setting Up Auxiliary Generator. Either auxiliary generator No. 1 (60 kw.) or auxiliary generator No. 2 (30 kw.) may be used to supply the supplementary ship's service bus. The auxiliary generator selector knife switch, on the auxiliary generator control panel, should be thrown to the left if it is desired to use auxiliary generator No. 1 and to the right if it is desired to use auxiliary generator No. 2 to supply power to the supplementary ship's service bus. If auxiliary generator No. 1 is to supply the supplementary ship's service bus, the auxiliary generator selector knife switch makes auxiliary generator No. 2 available for supplying power to the towing motor.

The bus selector knife switch should be thrown to the right to set up the circuit from the auxiliary generator selector knife switch to the supplementary ship's service bus. When the bus selector knife switch is thrown to the right, another circuit is set up from the exciter selector knife switch to the main ship's service bus, since the main ship's service bus must be supplied from an exciter when an auxiliary generator is to supply the supplementary ship's service bus.

The diesel engine corresponding to the selected auxiliary generator should now be started by the means provided.

Then throw the voltmeter switch, on the exciter

panel, to the position corresponding to the auxiliary generator being used to supply the supplementary ship's service bus.

After the engine comes up to speed, turn the knob of the corresponding auxiliary generator field rheostat until the voltmeter indicates that proper supplementary ship's service bus voltage has been established. This voltage should be checked occasionally.

The push-pull type supplementary ship's service bus control cut-out switch, on the auxiliary generator control panel, should now be pushed in to its "closed" position. The corresponding red indicating light, directly above the supplementary ship's service bus control cut-out switch, will be "on" to indicate that the main contactor for the supplementary ship's service bus is closed.

Overload Protection. Each auxiliary generator has a thermal overload relay in its armature circuit, so that, in the event the load of the supplementary ship's service bus causes the auxiliary generator supplying the supplementary ship's service bus to become overloaded, the corresponding overload relay will trip the main contactor for the supplementary ship's service bus as indicated by the red indicating light being "off" above the supplementary ship's service bus control cut-out switch on the auxiliary generator control panel. To restore operation the overload relay must be manually reset as explained in the description of the type TH thermal overload relays found elsewhere in this book.

Shutting Down Auxiliary Generator. To shut down the auxiliary generator supplying the supplementary ship's service bus, the supplementary ship's service bus control cut-out switch should be pulled out to its "open" position.

Then open the bus selector knife switch unless an exciter is to continue supplying power to the main ship's service bus. Also, open the auxiliary generator selector knife switch unless auxiliary generator No. 2 is being used to supply power to the towing motor.

Finally, stop the diesel engine.

Supplying Power to Towing Motor

Setting Up Auxiliary Generator. Since only auxiliary generator No. 2 can be used to supply power to the towing motor, the auxiliary generator selector knife switch should be thrown to the left to set up a circuit from auxiliary generator No. 2 to the towing motor bus. Throwing the auxiliary generator selector knife switch to the left also causes the field of auxiliary generator No. 2 to be connected to a separate source of excitation through the towing motor control which is not a part of this equipment.

The diesel engine for auxiliary generator No. 2 should now be started.

Shutting Down Auxiliary Generator. To shut down auxiliary generator No. 2, open the auxiliary generator selector knife switch unless auxiliary generator No. 1 is supplying power to the main ship's service bus or the supplementary ship's service bus.

Next, stop the diesel engine, for auxiliary generator No. 2.

Engine Starting Battery Charging. The double-pole disconnect switch on the distribution panel (not furnished) should first be closed and then press the battery charging cut-out switch located toward the left side of the engine starting battery charging cabinet. With either exciter or either auxiliary generator supplying the main ship's service bus, a trickle charge is now being supplied to the engine starting battery.

Pressing of the spring return reset push button or the starting of the port or starboard engine causes the battery charging voltage relay to drop out and thus start a high rate charge which will be indicated by the 0-50 ammeter. When the battery becomes fully charged, the battery charging voltage relay will pick up and cut out the high rate charging, thus leaving the battery on the line under trickle charge.

To disconnect the engine starting battery and its charging control from the main ship's service bus, the battery charging cut-out switch should first be pulled out to open its contacts and then the double-pole disconnect switch on the distribution panel (not furnished) should be opened.

CIRCUIT DESCRIPTION OF OPERATION

See Fig. 25X

Supplying Excitation and Control Bus Power

Setting Up Exciter. Assume that it is desired to use the starboard exciter to supply excitation and control bus power. The exciter selector knife switch KS1 should then be thrown to the left, thus connecting the starboard exciter to the excitation

and control buses P2 and N2 through the blades of knife switch KS1. The port exciter is then automatically connected to two clip studs of the bus selector knife switch KS3 through other blades of knife switch KS1, thus making the port exciter available for supplying the main ship's service bus.

The field cut-out switch SW2, for the starboard exciter, should be closed to complete the starboard exciter field circuit.

After the starboard engine is started and brought up to idling speed and the voltmeter switch is thrown to the "Starboard Exciter" position, the voltage adjusting rheostat RH2, for the starboard exciter, is operated to obtain the proper excitation and control bus voltage as indicated by the voltmeter. The starboard exciter voltage regulator VR-S then holds this voltage constant irrespective of speed changes of the starboard engine during propulsion operation.

If the port exciter were to be used to supply excitation and control bus power, knife switch KS1 would have to be thrown to the right and the circuit description of operation would be similar, applying to the controls for the port exciter in lieu of the starboard exciter.

Shutting Down Exciter. To shut down the starboard exciter, field cut-out switch SW2 should be opened to open the field circuit of the starboard exciter and knife switch KS1 should be opened to disconnect the starboard exciter from the excitation and control buses P2 and N2.

Supplying Main Ship's Service Bus Using an Exciter

Setting Up Exciter. Assuming that the starboard exciter is supplying excitation and control bus power, the port exciter is then available for supplying the main ship's service bus and is already connected to the bus selector knife switch KS3 through blades of the exciter selector knife switch KS1, as explained under "Supplying Excitation and Control Bus Power."

Knife switch KS3 should be thrown to the right to set up the circuit from the port exciter to the main ship's service bus; a circuit which will be completed when the main contactor C2 for the main ship's service bus is later closed. When knife switch KS3 is thrown to the right, a circuit is also set up from the auxiliary generator selector knife switch KS2 to the main contactor C1 for the supplementary ship's service bus. Consequently, the supplementary ship's service bus can be supplied from either auxiliary generator when an exciter is supplying the main ship's service bus.

Next, the field cut-out switch SW3, for the port exciter, should be closed to complete the port exciter field circuit.

After the port engine is started and brought up to idling speed and the voltmeter switch is thrown to the "Port Exciter" position, the voltage adjusting rheostat RH3, for the port exciter, is operated to obtain the proper main ship's service bus voltage as indicated by the voltmeter. The port exciter voltage regulator VR-P then holds this voltage constant irrespective of speed changes of the port engine during propulsion operation.

The control switch SW5, for the main ship's service bus, should be closed, thus completing a circuit from the positive terminal of the port exciter through the ammeter shunt and knife switch KS1, through an element of overload relay OL2, through knife switch KS3, through switch SW5, through the normally closed contacts of overload relay OL2, through the parallel circuit of normally closed KS3 auxiliary push button contacts and normally closed contacts of overload relays OL1 and OL3, through the normally closed reverse current relay contacts RC, through the reverse current relay potential coil RC, and back to the negative terminal of the port exciter through knife switches KS3 and KS1 and another element of overload relay OL2. The energizing of the reverse current relay potential coil causes opening of the normally closed RC contacts to insert additional resistance in the potential coil circuit and causes closing of the normally open RC contacts to complete the circuit of the main contactor coils C2. The energizing of these coils closes all normally open C2 contacts. Thus, the circuit is completed from the port exciter to the main ship's service bus and the red indicating light, in series with the auxiliary C2 contacts, will be energized to indicate that the main contactor C2 is closed. Also, auxiliary C2 contacts close in the main battery charging contactor BC1 coil circuit, so that engine starting battery charging may be obtained as explained later under "Engine Starting Battery Charging."

If the port exciter is being used to supply excitation and control bus power and the starboard exciter were to be used to supply the main ship's service bus, knife switch KS1 would be thrown to the right and

the circuit description of operation for supplying the main ship's service bus would be similar, applying to the controls for the starboard exciter in lieu of the port exciter.

Overload Protection. To protect the exciter against overload when supplying the main ship's service bus, the overload relay OL2 will open its normally closed contacts in the coil circuit of contactor C2, thus tripping the main contactor C2, and the red indicating light in series with the C2 auxiliary contacts will be de-energized to indicate that contactor C2 is open.

Shutting Down Exciter. Open the control switch SW5, thus interrupting the coil circuit of the main contactor C2 for the main ship's service bus, and as a result, the main contacts C2 will disconnect the main ship's service bus from the exciter and the auxiliary C2 contacts interrupt the circuit of the red indicating light.

Then open the field cut-out switch SW3, thus opening the field circuit of the port exciter.

The bus selector knife switch KS3 should be opened unless one of the auxiliary generators is supplying the supplementary ship's service bus.

The exciter selector knife switch KS1 should also be opened unless the starboard exciter is still to be used to supply power to the excitation and control buses P2 and N2.

Supplying Main Ship's Service Bus Using an Auxiliary Generator

Setting Up Auxiliary Generator. Referring to schematic diagram Fig. 25X, it will be seen that by means of the auxiliary generator selector knife switch KS2 either auxiliary generator may be used to supply the main ship's service bus.

Assume that it is desired to use auxiliary generator No. 1 to supply the main ship's service bus. The auxiliary generator selector knife switch KS2 should be thrown to the left, thus connecting auxiliary generator No. 1 to two clip studs of the bus selector knife switch KS3 through blades of knife switch KS2. Auxiliary generator No. 2 is then automatically connected to the towing motor circuit breaker through other blades of knife switch KS2.

Knife switch KS3 should be thrown to the left to complete setting up the circuit from auxiliary generator No. 1 to the main ship's service bus; a circuit which will be completed when the main contactor C2 for the main ship's service bus is later closed. Also, when the KS3 knife switch is thrown to the left, its cross-bar will open the normally closed auxiliary KS3 push button switch contacts.

After the engine for auxiliary generator No. 1 is started and comes up to speed and the voltmeter switch is thrown to the "Auxiliary Generator No. 1" position, the auxiliary generator No. 1 field rheostat RH4 is operated to obtain the proper main ship's service bus voltage as indicated by the voltmeter.

The control switch SW5, for the main ship's service bus, should be closed and circuit description of operation is the same as given in the preceding subsection, "Using An Exciter," except that the auxiliary normally closed KS3 contacts will be open.

If auxiliary generator No. 2 were to be used to supply the main ship's service bus, knife switch KS2 would be thrown to the right and the circuit description of operation would be similar except that the voltmeter switch would be thrown to the "Auxiliary Generator No. 2" position and the proper voltage would be obtained by operating field rheostat RH5 in lieu of RH4. Because of the position of knife switch KS2, the series field of auxiliary generator No. 2 will be connected "accumulative" when it is supplying the main ship's service bus. It will be noted that when auxiliary generator No. 2 is supplying the main ship's service bus, no source of supply is available for the towing motor.

Overload Protection. To protect auxiliary generator No. 1 against overload when supplying the main ship's service bus, the overload relay OL1 will open its normally closed contacts in the coil circuit of contactor C2, thus tripping the main contactor C2, and the red indicating light in series with the C2 auxiliary contacts will be de-energized to indicate that contactor C2 is open.

Auxiliary generator No. 2 is protected against overload by overload relay OL3 and the circuit description of operation is similar.

Shutting Down Auxiliary Generator. Open the control switch SW5, thus interrupting the coil circuit of the main contactor C2 for the main ship's service bus, and as a result, the main contactor C2 will disconnect the main ship's service bus from the auxiliary generator and the auxiliary C2 contacts interrupt the circuit of the red indicating light.

The bus selector knife switch KS3 should be

opened and the auxiliary KS3 contacts in the C2 contactor coil circuit are thus restored to their normally closed position.

The auxiliary generator selector knife switch KS2 should also be opened unless auxiliary generator No. 2 is being used to supply the towing motor.

Supplying Main Ship's Service Bus Reverse Current Protection

When an exciter or an auxiliary generator is supplying the main ship's service bus, the reverse current relay potential coil RC is energized as previously mentioned. The reverse current relay current coil RC, in the main ship's service bus supply circuit, is also energized and in a direction so that it aids the potential coil. If the current should reverse, that is, flow from the main ship's service bus battery to the machine supplying the main ship's service bus—as would be the case if the machine supplying the ship's service bus were shut down without first opening control switch SW5—the current coil of the reverse current relay RC will oppose the potential coil, thus returning the RC contacts, in series with the coils of contactor C2, to their normally open position and consequently tripping the main ship's service bus contactor C2. As a result, the main ship's service battery cannot discharge through the machine which had supplied the main ship's service bus.

Supplying Supplementary Ship's Service Bus

Setting Up Auxiliary Generator. Referring to schematic diagram Fig. 25X, it will be seen that by means of the auxiliary generator selector knife switch KS2 either auxiliary generator may be used to supply the supplementary ship's service bus.

Assume that it is desired to use auxiliary generator No. 1 to supply the supplementary ship's service bus. The auxiliary generator selector knife switch KS2 should be thrown to the left, thus connecting auxiliary generator No. 1 to two clip studs of the bus selector knife switch KS3 through blades of knife switch KS2. Auxiliary generator No. 2 is then automatically connected to the towing motor circuit breaker through other blades of knife switch KS2.

Knife switch KS3 should be thrown to the right to complete setting up the circuit from auxiliary generator No. 1 to the supplementary ship's service bus; a circuit which will be completed when the main contactor C1 for the supplementary ship's service bus is later closed. When knife switch KS3 is thrown to the right, a circuit is also set up from the exciter selector knife switch KS1 to the main contactor C2 for the main ship's service bus, since the main ship's service bus must be supplied from an exciter when an auxiliary generator is to supply the supplementary ship's service bus.

After the engine for auxiliary generator No. 1 is started and comes up to speed and the voltmeter switch is thrown to the "Auxiliary Generator No. 1" position, the auxiliary generator No. 1 field rheostat RH4 is operated to obtain the proper supplementary ship's service bus voltage as indicated by the voltmeter.

The control switch SW4, for the supplementary ship's service bus, should be closed, thus completing a circuit from the positive terminal of auxiliary generator No. 1 through the ammeter shunt and an element of overload relay OL1, through knife switches KS2 and KS3, through switch SW4, through the normally closed contacts of overload relays OL1 and OL3, through the supplementary ship's service bus main contactor coils C1, and back to the negative terminal of auxiliary generator No. 1 through knife switches KS3 and KS2 and another element of overload relay OL1. The energizing of coils C1 closes all normally open C1 contacts. Thus the circuit is completed from auxiliary generator No. 1 to the supplementary ship's service bus and the red indicating light, in series with the auxiliary C1 contacts, will be energized to indicate that the main contactor C1 is closed.

If auxiliary generator No. 2 were to be used to supply the supplementary ship's service bus, knife switch KS2 would be thrown to the right and the circuit description of operation would be similar except that the voltmeter switch would be thrown to the "Auxiliary Generator No. 2" position and the proper voltage would be obtained by operating field rheostat RH5 in lieu of RH4. Because of the position of knife switch KS2, the series field of auxiliary generator No. 2 will be connected "accumulative" when it is supplying the supplementary ship's service bus. It will be noted that when auxiliary generator No. 2 is supplying the supplementary ship's service bus, no source of supply is available for the towing motor.

Overload Protection. To protect auxiliary generator No. 1 against overload when supplying the

supplementary ship's service bus, the overload relay OL1 will open its normally closed contacts in the coil circuit of contactor C1, thus tripping the main contactor C1, and the red indicating light in series with the C1 auxiliary contacts will be de-energized to indicate that contactor C1 is open.

Auxiliary generator No. 2 is protected against overload by overload relay OL3 and the circuit description of operation is similar.

Shutting Down Auxiliary Generator. Open the control switch SW4, thus interrupting the coil circuit of the main contactor C1 for the supplementary ship's service bus, and as a result, the main contactor C1 will disconnect the supplementary ship's service bus from the auxiliary generator and the auxiliary C1 contacts interrupt the circuit of the red indicating light.

The bus selector knife switch KS3 should be opened unless an exciter is supplying the main ship's service bus.

The auxiliary generator selector knife switch KS2 should also be opened unless auxiliary generator No. 2 is being used to supply the towing motor.

Supplying Power to Towing Motor

Setting Up Auxiliary Generator. Referring to schematic diagram Fig. 25X, it will be seen that only auxiliary generator No. 2 can be used to supply power to the towing motor. Therefore, auxiliary generator selector knife switch KS2 should be thrown to the left, thus connecting auxiliary generator No. 2 to the towing motor circuit breaker. Because of the position of knife switch KS2, the series field of auxiliary generator No. 2 will be "differential" connected, when it is supplying the towing motor, so that the voltage will drop as load is applied and thus prevent heavy overloads during towing. Also, when the KS2 knife switch is thrown to the left, its cross-bar will close the normally open auxiliary KS2 push button switch contacts, thus energizing the coil of the towing motor transfer contactor TM. As a result, the normally closed TM contacts are opened and the normally open TM contacts are closed, thus connecting the shunt field of auxiliary generator No. 2 to the towing motor control. Consequently, the shunt field is separately excited when supplying power to the towing motor.

Shutting Down Auxiliary Generator. The exciter selector knife switch KS2 should be opened unless auxiliary generator No. 1 is being used to supply the main or supplementary ship's service bus. Opening knife switch KS2 opens the auxiliary KS2 contacts in the coil circuit of contactor TM, thus disconnecting the shunt field of auxiliary generator No. 2 from the towing motor control.

Engine Starting Battery Charging

The double pole switch on the distribution panel (not furnished) should be closed to connect the engine starting battery charging supply bus to the main ship's service bus.

The battery charging cut-out switch SW6, in the coil circuit of the main battery charging contactor BC1, should be closed.

When either an exciter or an auxiliary generator is set up to supply the main ship's service bus and the control switch SW5 is closed, the main contactor C2, for the main ship's service bus, will be closed as explained under "Supplying Main Ship's Service Bus." The closing of auxiliary C2 contacts, in the circuit of coil BC1, completes a circuit from the positive battery charging supply bus through auxiliary contacts C2, through cut-out switch SW6 and through the main battery charging contactor coil BC1 to the negative battery charging supply bus. The energizing of coil BC1 completes a circuit from the positive battery charging supply bus through one pole of the main battery charging contactor BC1, through a 50-A. fuse, through the trickle charge resistors, through a 0-5 ammeter, through the engine starting battery, through another 50-A. fuse and the other pole of the main battery charging contactor BC1 to the negative battery charging supply bus. Note will be taken that when the auxiliary C2 contacts are open in the BC1 contactor coil circuit, they automatically disconnect the starting battery from the main ship's service bus, and consequently the main ship's service battery, when the power supply to the main ship's service bus is disconnected and thus prevent the ship's service battery from discharging into the engine starting battery.

When the spring return reset push button PB1 is pressed or when either of the normally closed auxiliary contacts S1-P and S1-S, of the port and starboard engine starting contactors respectively, are opened due to starting of the port or starboard engine, the voltage across the coil of the battery charging voltage relay TVR is reduced to zero. This causes contacts TVR to close, thus completing a circuit from the positive battery charging supply

bus through one pole of contactor BC1, through a 50-A. fuse, the voltage relay contacts TVR, through the auxiliary battery charging contactor coil BC2, through another 50-A. fuse and the other pole of contactor BC1 to the negative battery charging supply bus. Energizing the coil BC2 closes the contacts BC2, completing the high rate charging circuit from the positive battery charging supply bus through one pole of BC1 and a 50-A. fuse, through the high rate charging resistors, through a 0-50 ammeter, through the contacts of the auxiliary battery charging contactor BC2, through the starting battery, through another 50-A. fuse and another pole of contactor BC1 to the negative battery charging supply bus. Thus, high rate charging of the engine starting battery is started whenever an engine is started, assuming of course, that the main ship's service bus is being supplied and the two pole switch, on the distribution panel, is closed.

When the safe full charge voltage is reached, the action of the battery charging voltage relay TVR will prevent overcharge by "picking up," thus opening its contacts in the circuit of coil BC2 resulting in the opening of the auxiliary battery charging contactor BC2. As a result, only the trickle charge circuit is maintained.

The high rate charging resistors have a maximum current carrying capacity of 40 amperes and may be adjusted to a lower value if desired. The trickle charge resistors are adjustable to obtain a charging rate of from approximately 3 amperes to below 1 ampere.

DESCRIPTION OF EQUIPMENT
GENERATOR CUT-OUT SWITCH CABINETS

See Fig. 1X

A generator cut-out switch cabinet is made up for both the port and starboard generators. The engine starting push button (6) is mounted just below the louvers on the right side of the cabinet. This is a single-pole serving return switch with normally open contacts. (For detail description of this switch refer to "Push Button Switches—10 amperes," page X-35.) Below the engine starting push button switch the generator cut-out switch (1) is mounted. (For detail description of this switch refer to "Generator Cut-out Switches," page X-37.)

The starboard generator field contactor (8) is mounted on a panel of insulating material in the

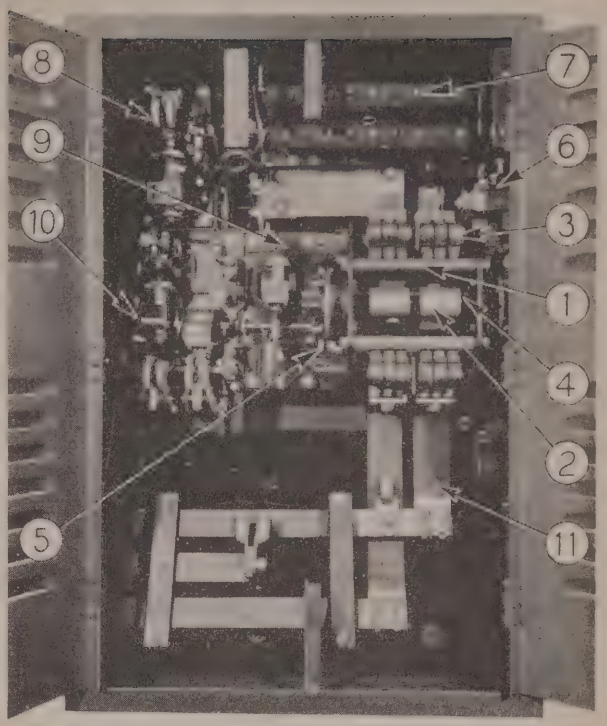


Fig. 1X
Generator Cut-Out Switch Cabinet

upper left hand corner of the starboard generator cut-out switch cabinet. This contactor has one normally open main pole with blowout and one set of normally open auxiliary contacts. (For detail description of this contactor refer to "Type D Multipole Contactors," page X-33.) To the right of the generator field contactor is a generator field resistor and the current limiting resistors (7) and below these resistors is a 1000 ampere shunt for the propulsion loop ammeter. Below the generator field contactor is the current limiting device (10). (For detail description of the current limiting device refer to "Type D Current Limiting Device," page X-37.) Adjacent to the current limiting device is the short circuit protective relay (9). This relay has a normally closed contact. (For detail description of this relay refer to "Short Circuit Protective Relays," page X-39.)

The port generator cut-out switch cabinet contains the same equipment as the starboard generator cut-out switch cabinet except for the omission of the 1000 ampere shunt, the current limiting device and the short circuit protective relay, and the addition of the main field contactor which is

located directly below the port generator field contactor. This contactor has one normally open main pole with blowout and set of normally open auxiliary contacts. (For detail description of the main field contactor refer to "Type D Multipole Contactors," page X-33.)

Maintenance. Inspect the electrical and mechanical connections in the cut-out switch cabinet every three months. Tighten any loose connections and clean the interior of the cabinet if necessary.

ENGINE ROOM CONTROL STAND

See Fig. 2X

The engine room control stand is constructed of angle iron and sheet steel. The sides and rear plates are of expanded metal to allow ventilation for the resistors of the generator and motor field controllers.

There are three meters and three indicating lights mounted on the top of the control stand. Viewing the control stand from the front, the meter (2) to the left is the propulsion loop ammeter. The center meter (1) is the r.p.m. meter and the meter (3) to the right is the voltmeter for measuring propulsion motor and generator voltages. The red lamp (4) is the excitation indicating lamp, the blue lamp (5) is the engine starting failure indicating lamp and the white lamp (6) is the indicating lamp for current limiting device operation.

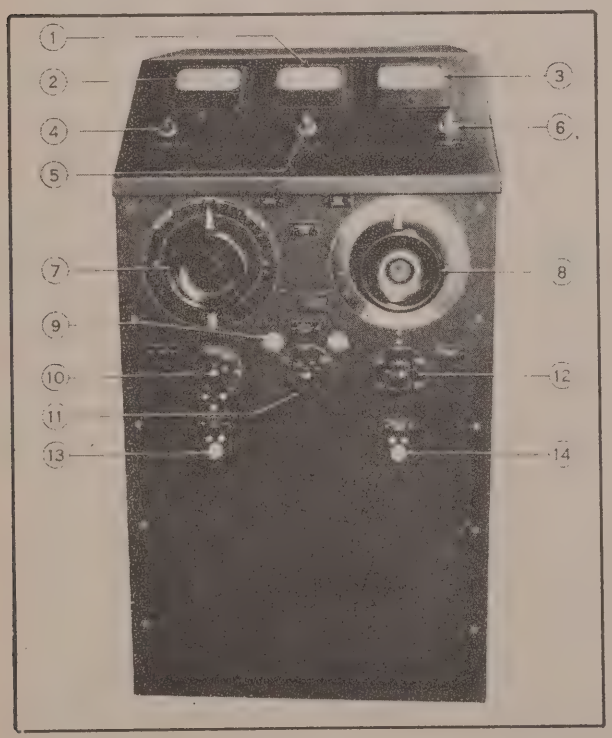


Fig. 2X
Engine Room Propulsion Control Stand

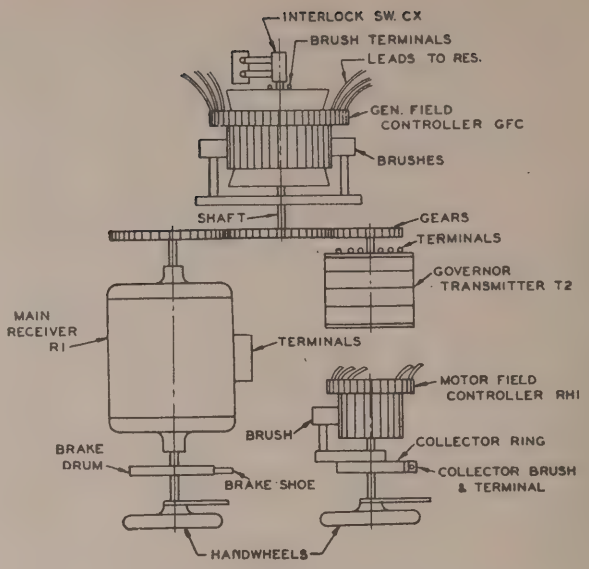


Fig. 3X
Main Speed and Motor Field Controller

On the front of the panel near the top are two handwheels (7) and (8). Handwheel (8) operates the motor field controller which is described under sub-section, "Motor Field Controller." Handwheel (7) operates the speed controller which consists of the generator field controller and the transmitter for the engine governor receivers. Referring to Fig. 3X, the main receiver, for remote control operation, is in tandem with the speed control handwheel. Then, by means of gears, the speed control handwheel shaft is connected to a generator field controller and a transmitter for the engine governor receivers. These units are described under sub-sections, "Generator Field Controller" and "Transmitter."

Directly below the speed control handwheel, on Fig. 2X, is the selector switch (10) for selecting manual or remote control. This switch is described under sub-section, "Selector Switch." Directly below the motor field controller is the voltmeter switch (12) for connecting the desired propulsion motor or generator to the voltmeter (3), and between the voltmeter and selector switches is the ground detector switch (11) for checking the leg of each generator to ground. A ground will be indicated by white indicating lights (9). The voltmeter switch (12) is a double-pole, five position rotary switch and the ground detector switch is a

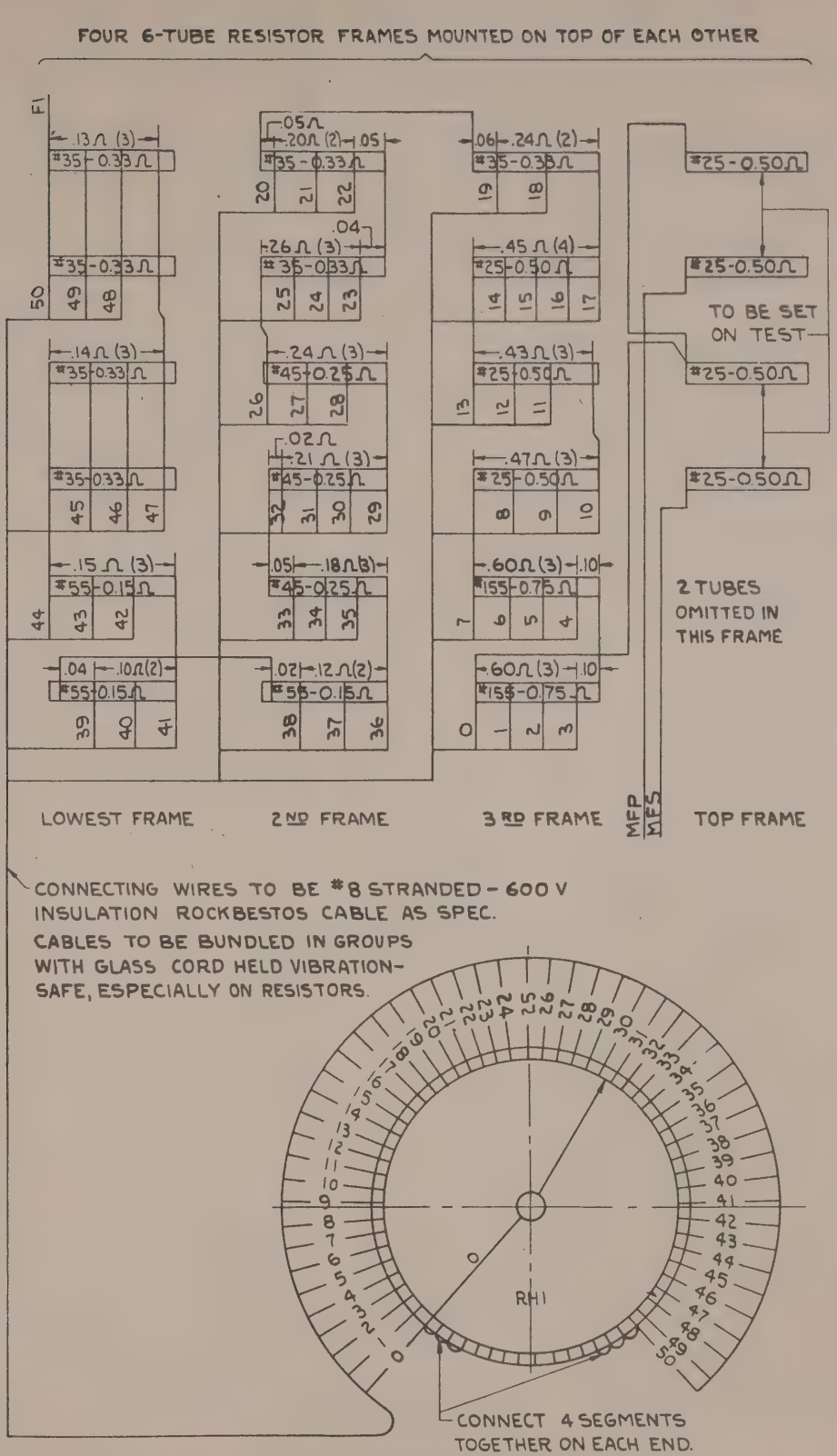


Fig. 4X
Motor Field Controller—Wiring Diagram

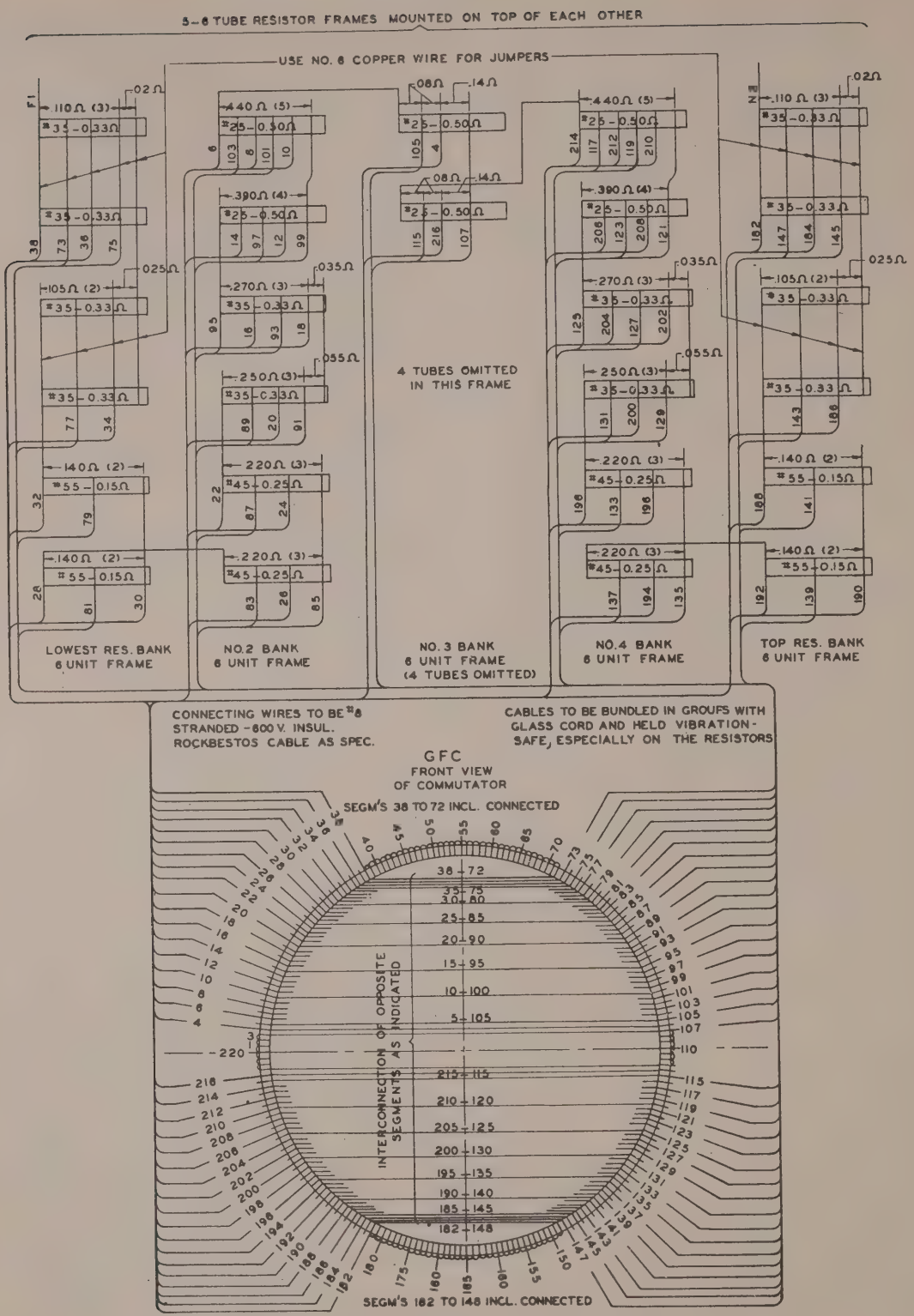

5-6 TUBE RESISTOR FRAMES MOUNTED ON TOP OF EACH OTHER
USE NO. 6 COPPER WIRE FOR JUMPERS
4 TUBES OMITTED IN THIS FRAME
LOWEST RES. BANK 6 UNIT FRAME
NO.2 BANK 6 UNIT FRAME
NO. 3 BANK 6 UNIT FRAME (4 TUBES OMITTED)
NO.4 BANK 6 UNIT FRAME
TOP RES. BANK 6 UNIT FRAME
CONNECTING WIRES TO BE #8 STRANDED -600 V. INSUL. ROCKBESTOS CABLE AS SPEC.
CABLES TO BE BUNDLED IN GROUPS WITH GLASS CORD AND HELD VIBRATION-SAFE, ESPECIALLY ON THE RESISTORS
GFC
FRONT VIEW OF COMMUTATOR
SEGM'S 38 TO 72 INCL. CONNECTED
INTERCONNECTION OF OPPOSITE SEGMENTS AS INDICATED
SEGM'S 182 TO 148 INCL. CONNECTED

Fig. 5X
Generator Field Controller—Wiring Diagram

double-pole, three position rotary switch. (For detail description of these two switches refer to page X-36—"Rotary Switches Type W.")

Push button switch (13) is the field cut-out switch which when open, removes all excitation from the propulsion motors and generators, and push button switch (14) is the governor control cut-out switch which when open, interrupts one leg of the governor control system. Both of these switches are single-pole, manual return, unfused switches with normally open contacts. (For detail description of these push button switches refer to "Push Button Switches—30 ampere," page X-36.)

Motor Field Controller

The resistors for the motor field controller are connected to segments which are stacked together and insulated from each other similar to the commutator of a d. c. motor or generator Two brushes held in two brush-holders ride on this commutator to vary the motor field current by moving the handwheel on the front of the motor field controller. A counter-balance is provided to equalize the weight of the brush arm so as to prevent the changing of the brush position due to vibration. Turning the handwheel counter-clockwise adds resistance to the motor field circuit, decreasing the field current and thus increasing motor speed.

Maintenance. The only maintenance required is that of keeping the contact surface clean. Cleaning of the commutator may be done with fine sandpaper—*do not* use emery cloth or other abrasives made of conductive material.

Generator Field Controller

The resistors of the generator field controller are connected to segments which are stacked together and insulated from each other similar to the commutator of a d.c. motor or generator. There are eight brushes in four brush-holders (two brushes per brush-holder) that ride on the commutator. The brushes are 180° apart, and as a result, they counter balance each other. Thus, the weight of the brush arms is equalized and so prevents changing of the brush position due to vibration. The commutator segments to which the center point of the resistors is connected, is the "Off" position or point of zero field current. The area of zero field current is made wider than the brushes, that is, consists of several segments, in order that extreme mechanical accuracy will not be required since there is a slight angular lag between the positions of the remote controller and those of the brushes due to physical tolerances of the gears and the electrical control system.

Maintenance. The bearings are both sealed ball bearings requiring no oil. The surface of the contact segments should be kept clear of dirt. Cleaning of the segments may be done with fine sandpaper—*do not* use emery cloth or other abrasives made of conductive material. Oil on the contact surface must be avoided, otherwise sparking and deterioration will result. The use of a clean rag dampened with carbon-tetrachloride will help to keep the contact surface free from oil.

Avoid getting the brushes at too great a pressure because a great amount of friction will cause errors in positioning. However, the brush pressure should be enough to avoid sparking during regular operation. (A slight amount of sparking may result from quick movement, but if sparking is present only during such periods, no damage is being done.)

Transmitter

The transmitter is as shown on Fig. 6X except that it does not have a positioning wheel and the resistors are mounted perpendicular to the operating shaft. The transmitter consists of four sections of rings and segments stacked together to operate as a unit. The sections are electrically insulated from each other. The brushes for these four sections are located at the ends of four moving arms and ride on the inner surface of the rings and segments. A spring in each moving arm provides the contact

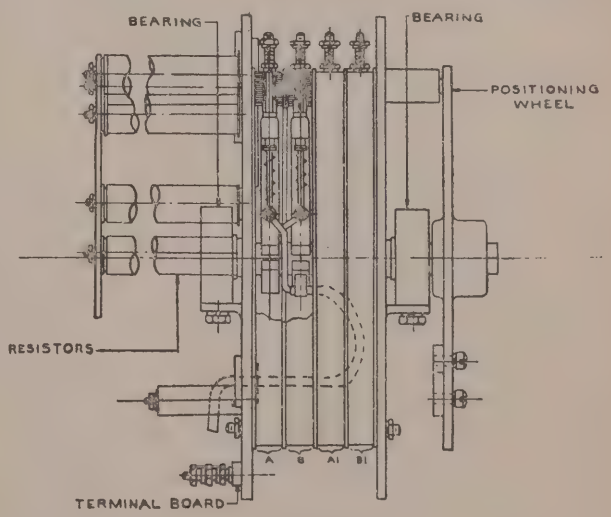


Fig. 6X
Transmitter

pressure for the brush. The four arms are supported in tandem along the length of the operating shaft. Four flexible leads provide the connection from each brush to a terminal block and the terminal block provides the external electrical connections.

Maintenance. The only maintenance required is that of keeping the parts clean. Cleaning of the contact segments may be done with fine sandpaper—avoid abrasives which are made of conductive materials, such as emery cloth.

The bearings are sealed ball bearings and thus *no lubrication* whatever is required or should be attempted.

Care must be taken when wiring to be sure that the connections of external leads are according to the wiring diagrams furnished, since burned out transmitter resistors can quickly result from incorrect wiring. Keep metal objects out of the transmitter when in operation.

Main Receiver

The main receiver is similar in appearance to a small induction motor. All six leads terminate in the terminal box on the side of the receiver. The receiver has a specially wound stator and the stator leads are brought directly to the terminal box through the stator frame. The two rotor leads are connected to a movable terminal block on the rotor shaft, and from this terminal block, two extremely flexible connectors are brought out through a bushing in the receiver end cap to the terminal box through the terminal box bushing.

Maintenance. The receiver is totally enclosed and its rotor is mounted on sealed ball bearings requiring no lubrication.

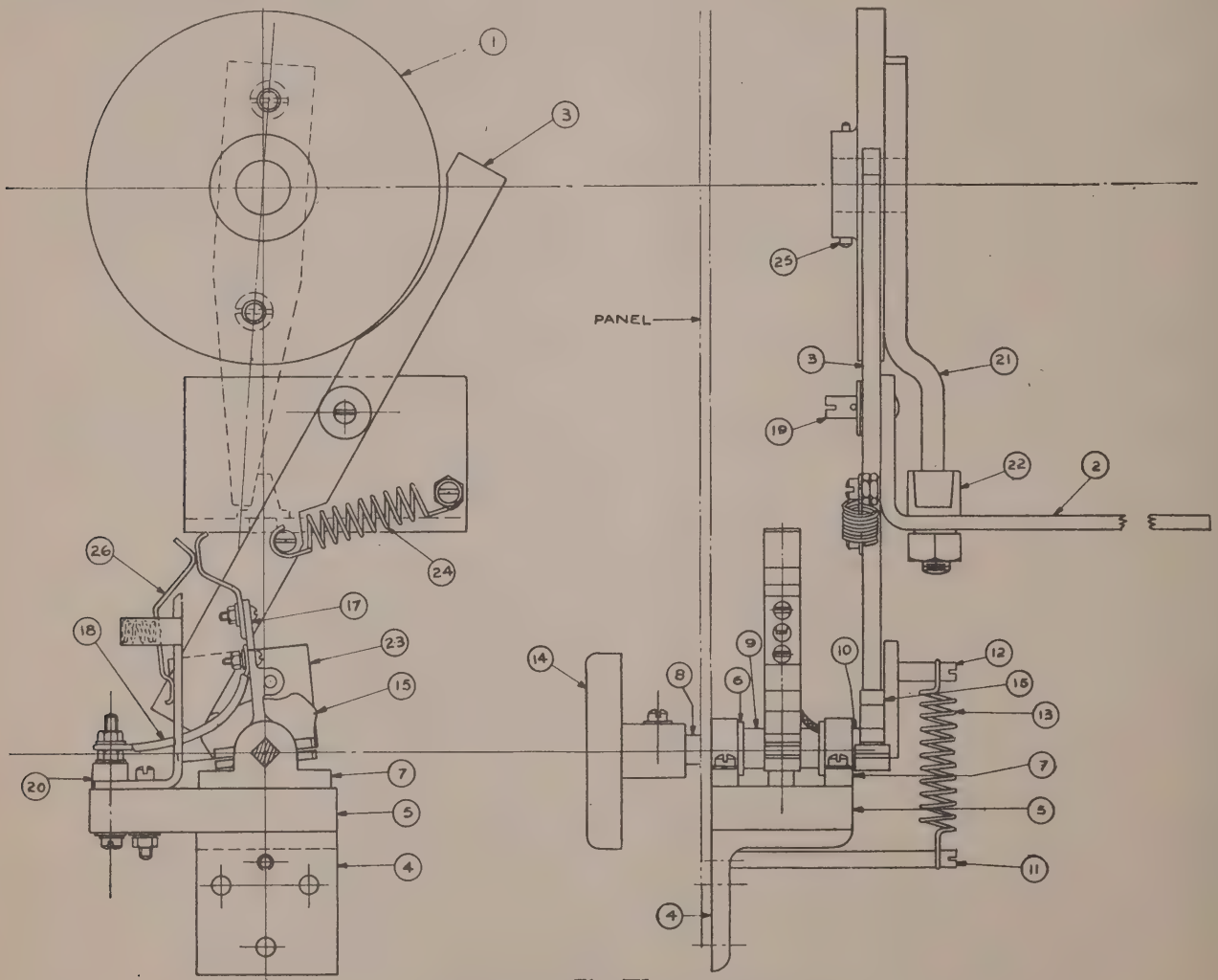


Fig. 7X
Selector Switch with Friction Device

Selector Switch

The selector switch is a two position switch which operates a brake on the speed control handwheel and main receiver shaft as shown on Fig. 3X and Fig. 7X. Referring to Fig. 7X, when the switch is turned to the "Remote Control" position, the contacts are closed and a cam (15) engages the brake shoe (3) against the action of spring (24), thus causing the brake drum (1), on the main receiver shaft, to be free from the brake shoe (3). When the switch is turned to the "Manual Control" position, the contacts are opened and cam (15) disengages the brake shoe (3) to permit the brake shoe to be turned counter-clockwise about its pivot point and exert a pressure against brake drum (1) by means of spring (24). Spring (13) gives the switch a snap action when turning from one position to the other.

The purpose of the brake is to cause the speed controller to stay in a given set position when the handwheel is released, thus preventing vibration from causing undesirable changes in the speed controller position. However, the braking action is not great enough to require excessive effort on the handwheel. No brake action is necessary when the speed controller is operated by remote control since the torque of the main receiver holds the speed controller in the position determined by the remote control transmitter.

Maintenance. The contacts on the switch should be examined periodically for wear and cleaned when necessary. Contacts should be replaced when the wear is about $\frac{1}{32}$".

Use no lubricants.

PILOT HOUSE CONTROL STAND

There are two control stands; one live and one dummy stand. When standing on the operator's side of the control stands, the live stand is to the operator's right and the dummy stand is to the left. The control handle shafts of the two control stands are connected together so that they act as a unit. The speed control handle is on the right side of the live control stand and on the left side of the dummy control stand.

In the live control stand, bevel gears and shafting connect the speed control handle to the remote control transmitter mounted in the lower part of the stand. The transmitter has four sections of segments, as shown on Fig. 6X, and these sections are stacked together to operate as a unit but are electrically insulated from each other. The brushes of the four sections are located at the ends of four moving arms and ride on the inner surface of the segments. A spring in each moving arm provides the contact pressure for the brush. The four arms are supported in tandem along the operating shaft. Four flexible leads provide the connection from each brush to a terminal block and the terminal block provides the external electrical connections. A positioning plate, located below the four transmitter sections, holds the transmitter in its various speed positions.

Maintenance. The only maintenance required is that of keeping the parts clean. Cleaning of the contact segments may be done with fine sandpaper—avoid abrasives which are made of conductive materials, such as emery cloth.

A few drops of oil should be used once a month on the gears on the control handle and transmitter shafts. All the bearings are sealed ball bearings and thus *no lubrication* whatever is required or should be attempted on them.

Care must be taken when wiring to be sure that connections of external leads are according to the wiring diagrams furnished since burned out transmitter resistors can quickly result from incorrect wiring. Keep metal objects out of the transmitter when in operation.

ENGINE STARTING CONTACTOR ASSEMBLY

The engine starting contactor assembly consists of four type EE, 300 ampere, single pole contactors with blowouts mounted on a base of insulating material which in turn is mounted in a steel cabinet. Each contactor has one normally open and one normally closed set of 10 ampere auxiliary contacts. (For detail description of these contactors refer to "Type EE Contactors," page X-34.)

STARTING BATTERY CHARGING CABINET

The starting battery charging equipment is mounted in a steel cabinet with louvers at the top for resistor ventilation. The three meters on the front of the cabinet are from left to right: The trickle charge ammeter; the battery voltmeter; the high rate charge ammeter. The push button to the left side of the cabinet is the battery charging cut-out switch. This switch is a single-pole,

normally open, manual return push button switch. The push button to the right side of the cabinet is the reset switch for high rate charging. This switch is a single-pole normally closed, spring return push button switch. (For detail description of these push button switches refer to "Push Button Switch—10 amperes," page X-35.)

On the front cover is mounted a type TVR special voltage relay as furnished by the Electric Storage Battery Company for use in connection with storage batteries. This is a sealed device requiring no maintenance.

Inside the cabinet two 50-ampere contactors are mounted on a panel of insulating material. One of the 50-ampere contactors is a type D, size B, single-pole with blowout and the other is a type D, size C, double-pole with blowouts. (For detail description of these contactors refer to "Type D Multipole Contactors," page X-33.)

To the left of the above mentioned contactors are the line fuses and directly below the fuses is the 1 microfarad condenser for the TVR relay contacts.

The high rate charge and trickle charge resistors are mounted in the upper portion of the cabinet.

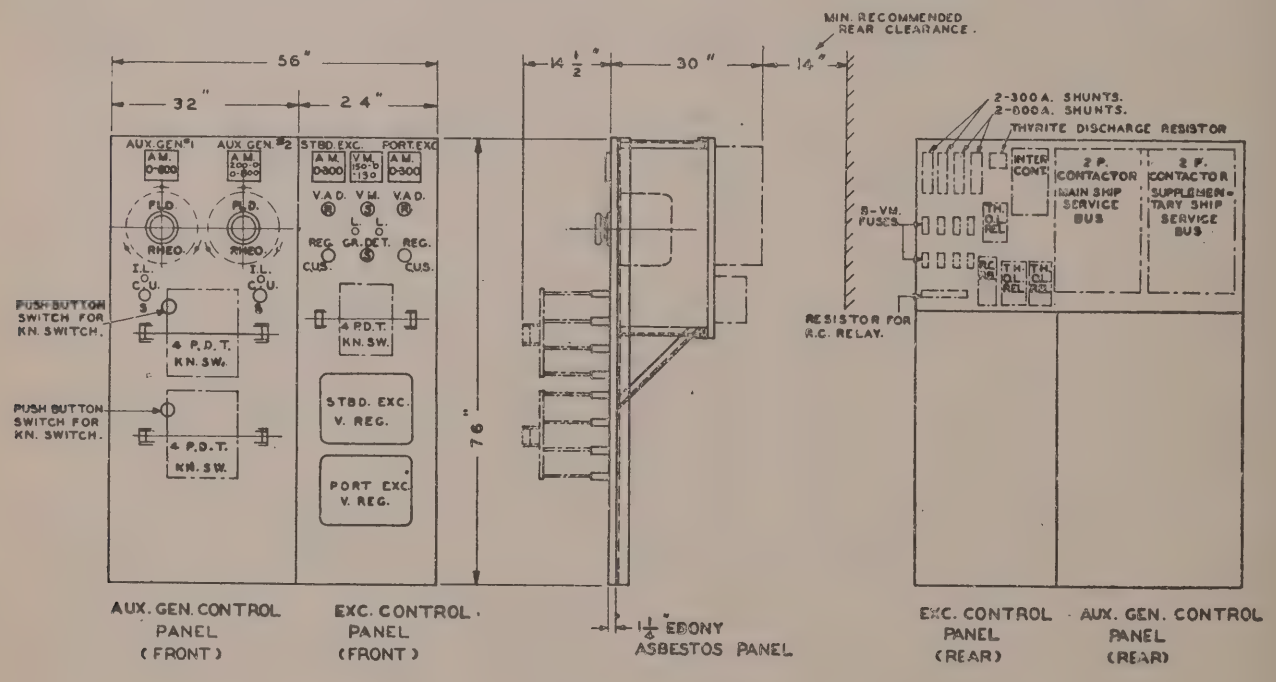
EXCITER AND AUXILIARY GENERATOR CONTROL PANELS

See Fig. 8X

The exciter and auxiliary generator control equipment is mounted on panels of ebony asbestos. The two panels are mounted as a unit on a frame of angle iron which also supports a small sub-panel of ebony asbestos in the rear.

In the upper left hand corner of the auxiliary generator control panel is the ammeter for auxiliary generator No. 1 and to the right is the ammeter for auxiliary generator No. 2. Directly below the two ammeters are two field rheostats; the one on the left is for auxiliary generator No. 1 and the one on the right is for auxiliary generator No. 2.

To the left and below the left hand field rheostat is a red indicating lamp for the main contactor for the supplementary ship's service bus and directly below this red lamp is the supplementary ship's service bus cut-out switch. To the right and below the right hand field rheostat is the main ship's service bus red indicating lamp and cut-out switch. These two cut-out switches are both single-pole, manual return, non-fused push button switches



14" MIN. = RECOMMENDED SIDE CLEARANCE ON LEFT OR RIGHT SIDE OF PANELS.

APPROX. WEIGHT = 1000 LBS.

Fig. 8X
Auxiliary Generator and Exciter Control Panel

with normally open contacts. (For detail description of these cut-out switches refer to "Push Button Switches—30 amperes," page X-36.)

Two 4 P.D.T. knife switches are mounted on the lower portion of the auxiliary generator control panel. The upper knife switch is the auxiliary generator selector switch and the lower one is the bus selector switch. When either of these knife switches is thrown to the left, their cross-bars will operate auxiliary spring return push button switches. These push button switches are both single-pole, spring return push button switches, the upper switch having normally open contacts and the lower switch having normally closed contacts. (For detail description of these auxiliary switches refer to "Push Button Switches—10 amperes," page X-35.)

On the exciter control panel there are three meters near the top. From left to right these meters are: The ammeter for the starboard exciter; the voltmeter for reading the voltage across either exciter or auxiliary generator; and the ammeter for the port exciter. Directly below the voltmeter is the voltmeter switch for connecting the voltmeter to the desired exciter or auxiliary generator. This switch is a six-pole, three position rotary switch. (For detail description of the voltmeter switch refer to "Rotary Switches—10 amperes," page X-36.) To the left of the voltmeter switch is the voltage adjusting rheostat for the starboard exciter and to the right is the voltage adjusting rheostat for the port exciter.

Directly below the voltmeter switch are two white indicating lamps for ground detection, and directly below these lamps is the ground detector switch for checking for ground in either exciter or auxiliary generator circuit. This switch is a six-pole, three position rotary switch. (For detail description of this switch refer to "Rotary Switches—10 amperes," page X-36.) To the left of the ground detector switch is the field cut-out switch for the starboard exciter and to the right is the field cut-out switch for the port exciter. These two switches are both single-pole, manual return, unfused push button switches with normally open contacts. (For detail description of these field cut-out switches refer to "Push Button Switches—30 amperes," page X-36.)

In the center of the panel is mounted a 4 P.D.T. knife switch which is the exciter selector switch. Below this knife switch are two voltage regulators; the upper one for the starboard exciter and the lower one for the port exciter. (For a detail description of voltage regulators refer to "Type R-250 Voltage Regulator," page X-39.)

Additional equipment is mounted on the sub-panel in the rear of the exciter and auxiliary generator control panels. To the right, when facing the rear of the control sections, is the main contactor for the supplementary ship's service bus and this contactor has two normally open main poles with blowouts and one set of normally open auxiliary contacts. To the left of this contactor is mounted the main contactor for the main ship's service bus and this contactor has two normally open main poles with blowouts and two sets of normally open auxiliary contacts. To the left of the main ship's service bus contactor and close to the top of the panel is the towing motor transfer contactor and this contactor has two sets of normally open contacts and two sets of normally closed contacts. (For detail description of these three contactors refer to "Type D Multipole Contactors," page X-33.)

In the upper left hand corner of the sub-panel are two 300 ampere shunts and two 800 ampere shunts used with the exciter and auxiliary generator ammeters respectively. Below the shunts are mounted all voltmeter circuit fuses and the resistor for the reverse current relay potential coil circuit. Between the shunts and the towing motor transfer contactor is the thyrite discharge resistor for the field of auxiliary generator No. 2 when it is disconnected from the towing motor control.

Directly below the thyrite discharge resistor is the overload relay for the exciters when connected to the main ship's service bus and this relay has one set of normally closed contacts. Below the towing motor transfer contactor are two more overload relays; the one on the right is for auxiliary generator No. 1 and the one on the left is for auxiliary generator No. 2 and each of these two overload relays has two sets of normally closed contacts. (For detail description of these three overload relays refer to "Type TH Thermal Overload Relays," page X-44.) To the left of the overload relays for the auxiliary generators is the main ship's service bus reverse current relay. (For detail description of this reverse current relay refer to "Type FS Reverse Current Relays," page X-45.)

PILOT HOUSE METER CABINET

The equipment for the pilot house meter cabinet is mounted in a steel cabinet. It consists of an r.p.m. indicator and a red lamp which is the excitation indicating lamp.

GOVERNOR RECEIVER

The governor receiver is similar in appearance to a small induction motor. All six leads terminate in the terminal box on the side of the receiver. The receiver has a specially wound stator. The two rotor leads are connected to a movable terminal block and from the terminal block two extremely flexible connectors are brought out through a bushing in the end cap to the terminal box through the terminal box bushing. The four stator leads are brought directly to the terminal box through the stator yoke.

Maintenance. The receiver is totally enclosed and the rotor is mounted on sealed ball bearings requiring *no lubrication.*

GENERATOR FIELD CONTROLLER

Fig. 9X is an elementary diagram of connections of the Generator Field Controller unit. The resistors are connected between positive and negative and the center point of the resistors is connected to the stationary contact segments forming the "Off" position of the two brushes. Intermediate resistor taps are connected to intermediate stationary segments as shown. However, the actual number of segments is of course greater than the number shown. The shaded areas indicate the bars of the "Off" position and the field maintaining rings in the engine speed control range.

The position shown is the "Off" position or point of zero field current since the field is short circuited and connected to a point of zero potential. As the brushes are caused to rotate, by movement of the handwheel, in the direction of the circular arrow marked "Ahead," field current and consequently generated voltage is brought up progressively until brush A is directly connected to the positive bus and brush B is directly connected to the negative bus represented by the shaded areas marked "Engine Speed Control Range." When the brushes reach these areas the field current reaches its maximum value and the further movement causes the TM unit to act upon the governor receivers as described in an instruction bulletin covering the

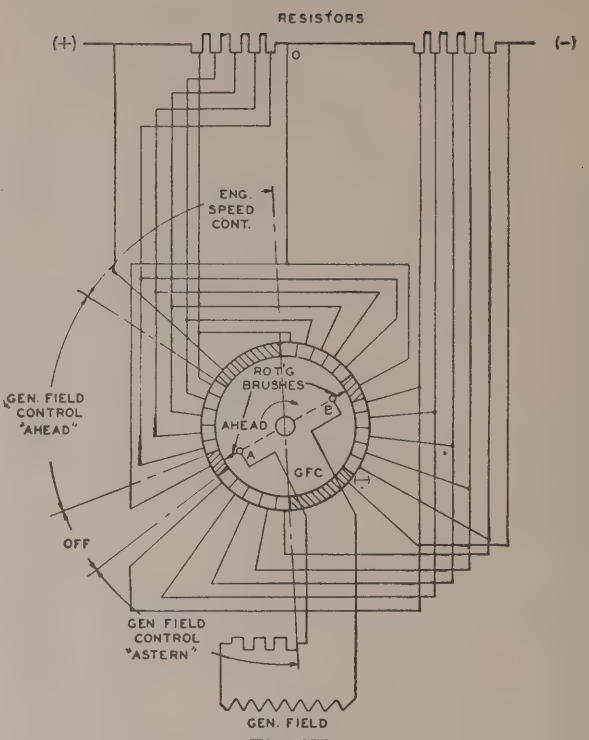


Fig. 9X
Elementary Diagram of Generator Field Controller

operation of the governor positioning system. No change in field current occurs during engine speed control.

Movement of the brushes, from the "Off" position, in a direction opposite to that of the circular arrow marked "Ahead" causes the field current to be increased progressively in the reverse direction until brush A becomes full negative and brush B becomes full positive. This method of reversing the generator field current does not involve the opening of the field circuit at any time.

GOVERNOR POSITIONING SYSTEM

Fig. 11X shows schematically the circuits involved when the system is applied to the control of the governor receiver of one engine. The receiver is located at the governor where it acts upon the engine throttle to change speed settings in accordance with positions of the transmitter. For control of more than one engine, more receiver stators will be connected in parallel, the number of receivers being the same as the number of engines.

The receiver, shown schematically on Figs. 10X and 11X, has specially designed stator windings A

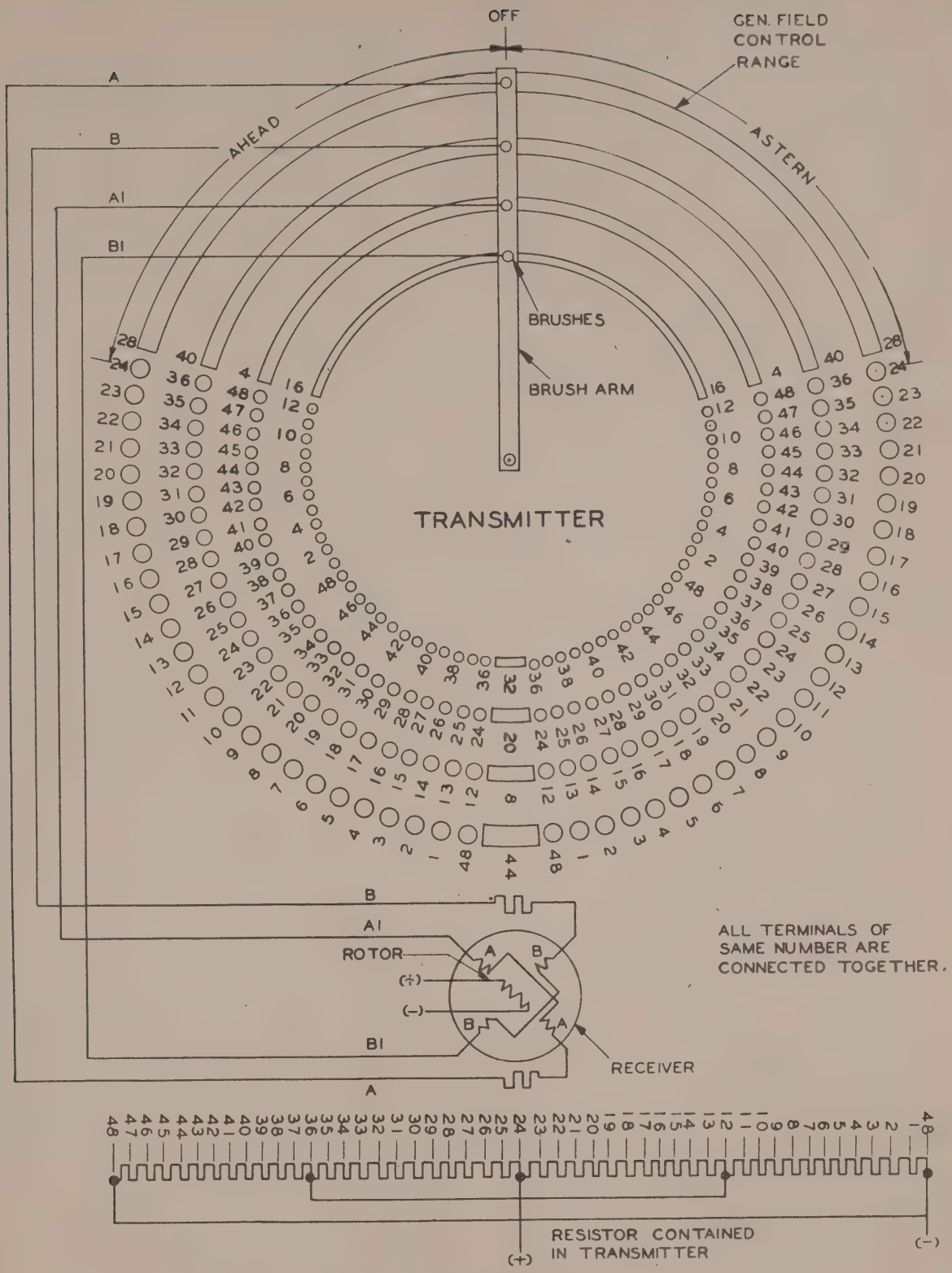
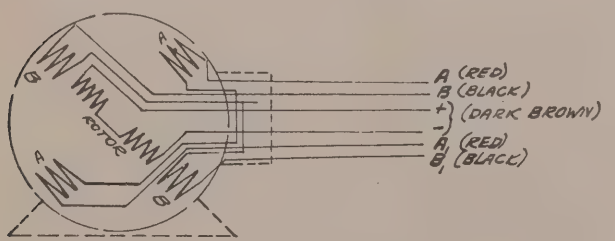


Fig. 11X
Governor Positioning System

and B which are connected to the brushes of the transmitter through its terminal board and the rotor is connected directly to the d.c. bus.

The transmitter sections are represented on Fig. 11X as four concentric sections of a faceplate for the sake of clarity. The four rings at the top represent the "Generator Field Control Range" or "Inactive" portion of the transmitter and receiver, where the generator field controller is operated and the engines are run at constant (idling) speed. To the left of the vertical centerline is the "Ahead" range and to the right of the vertical centerline is the "Astern" range of operation. It will be kept in mind that the governor speed setting must be moved in the same direction to increase speed, whether the propeller rotation is "Ahead" or "Astern." For this reason, moving the transmitter brushes from the "Off" position toward "Full Speed Astern" must produce the same direction of rotation of the receiver rotor as moving the brushes from the "Off" position toward "Full Speed Ahead." This is accomplished by the transmitter. In the inactive range, the receiver is not disconnected but is held at the idling speed position by reason of the stator field being maintained at a fixed position. The circuit is never opened and thus arcing is not present.

Voltage variations in the d.c. source do not affect the positioning. They affect the torque but only by an amount proportional to the variation. The governor positioning system is both amplifying and non-reversing. That is, the torque required to operate the transmitter is very small compared to that obtainable from the receiver, and torque applied to the receiver will not cause torque on the transmitter. Overtravel of the receiver is practically zero and the receiver will not oscillate. That is, after a movement of the transmitter the receiver comes to a definite stop a slight fraction of a second after



Resistance:
Phase A-A1 — 195 ohms (Red)
Phase B-B1 — 195 ohms (Black)
Rotor Coil — 610 ohms (+—) or P21 and N2

Fig. 10X
Schematic Receiver Connections

the transmitter does, and for this reason no dampening devices, clutches or brakes are required.

On Fig. 11X, only twenty-five of the steps are between the mechanical stops of the receiver. That is, from segments 24 to 48, on the outer section, the receiver can rotate. Thus, from steps 24 to 28 and 48 to 44 it moves against a stop, providing additional assurance that the receiver comes to the required position at each end of its travel.

In the transmitter, all segments of the same number are connected together. That is, all 2's together, all 3's together, etc. Assume the brush arm is on the four segments 24-36-48-12 (reading from outside toward the center). Tracing this through the circuit, we find that winding A of the receiver is energized directly from positive to negative and winding B is short circuited. That is, winding A has full voltage impressed upon it and winding B is at zero voltage. This causes the rotor to move into a position coincident with winding A.

Moving the brush arm downward (the increase speed direction) causes resistance to be inserted into the circuit of winding A and causes resistance to be removed from the circuit of winding B. Thus, through each progressive step, the current in winding A is decreased and the current in winding B is increased. When step 12-24-36-48 (reading from outside toward the center) is reached, winding A is at zero voltage and winding B has full voltage impressed upon it and the rotor has then moved to a position coincident with winding B. Owing to the special design of the resistance steps and arrangement of the stator winding together with the rotor design, there are corresponding positions of equal torque as the transmitter brush arm moves over the stationary segments.

Further movement of the brush arm causes the current to decrease in winding B and increase in winding A, however, the current in winding A will be in a direction reversed from its previous direction before arriving at step 12-24-36-48. When the brush arm reaches step 48-12-24-36 (reading from outside toward the center), the receiver will have traveled 180 degrees.

It will be noted at the bottom of the transmitter diagram that, as the arm comes to the full speed position, the last step is from 48 to 44, 12 to 8, 24 to 20 and 36 to 32, leaving out the intermediate steps of 47-45, 11-9, 23-21 and 35-33, respectively. This is for the reason that the last step is composed

of several times as many degrees (in terms of the receiver rotor) as the other steps and thus allows the receiver to be pulled definitely against its mechanical stop as the brush arm is moved to the position of maximum speed. This insures the receiver always reaching the full speed position. Also, from the rings at the top of the transmitter, the first step is from 28 to 24, 40 to 36, 4 to 48 and 16 to 12, leaving out the intermediate steps 27-23, 39-37, 3-1 and 15-13, respectively. This insures the receiver being pulled against the slow speed stop when the speed control handle is moved to that position.

This description is general and different applications require different numbers of steps in the transmitter. For the actual number of steps refer to the wiring diagram of the governor transmitter.

Direction of Receiver Rotation

If, after installation, the receiver runs opposite to the desired direction, the correction can be made by interchanging leads A and A1 or leads B and B1. (See Fig. 10X.) The internal connections to the rotor are made by means of flexible leads and an internal rotor stop is provided to prevent twisting off of these leads. Thus, if the rotor strikes the stop when leads A and A1 or leads B and B1 are interchanged, it will be necessary to disengage the gear sector from the receiver gear and then reverse the field of the receiver. Then re-engage the gear sector with the receiver gear.

Governor Adjustment

Set the speed controller handwheel at some arbitrary intermediate position between engine idling speed and full speed and estimate by the transmitter position what this speed should be. Then set the governor gear sectors so that the gears of the receivers engage corresponding teeth of the gear sectors and adjust these gear sectors on their shafts so that the speed is the same on all engines. Then move the speed controller to the "Off" position and to the full speed position, adjusting the mechanical stops at each position so that all engines have the proper idling and full speeds.

MAIN POSITIONING SYSTEM

Fig. 12X shows schematically the circuits involved in a main positioning system. The receiver is located in the engine room control stand where it acts upon the engine room speed controller in accordance with positions of a remote control transmitter located at some remote control station. The receiver has specially designed stator windings A and B which are connected to the brushes of a remote control transmitter through its terminal board and the rotor is connected directly to the d.c. bus.

With a direct current source applied to the system, the receiver rotor will take definite positions corresponding to those of the remote control transmitter. Voltage variations in the d.c. source do not affect the positioning. They affect the torque only by an amount proportional to the variation. The main positioning system is both amplifying and non-reversing. That is, the torque required to operate the remote control transmitter is very small compared to that obtainable from the receiver, and torque applied to the receiver will not cause torque on the remote control transmitter. Overtravel of the receiver is practically zero and the receiver will not oscillate. That is, after a movement of the remote control transmitter the receiver comes to a definite stop a slight fraction of a second later, and for this reason no dampening devices, clutches or brakes are required. The same torques exist for all positions.

The transmitter sections are represented on Fig. 12X as four concentric sections of a faceplate for the sake of clarity and in the transmitter, all segments of the same number are connected together. That is, all 2's together, all 3's together, etc. The number of stationary segments of a transmitter determines the number of possible steps. Fig. 12X shows a 37 step transmitter—18 steps in each direction. However, the actual number of steps in a particular application may be different. For the actual number of steps refer to wiring diagram of remote control transmitter.

Assume the brush arm is in the "Off" position. That is, on the four segments 36-9-18-27 (reading from outside toward the center). Tracing this through the circuit, we find that winding A of the receiver is energized directly from positive to negative and winding B is short circuited. That is, winding A has full voltage impressed upon it and winding B is at zero voltage. This causes the rotor to move into a position coincident with winding A.

Moving the brush arm in the "Ahead" direction causes resistance to be inserted into the circuit of winding A and causes resistance to be removed from the circuit of winding B. Thus, through each

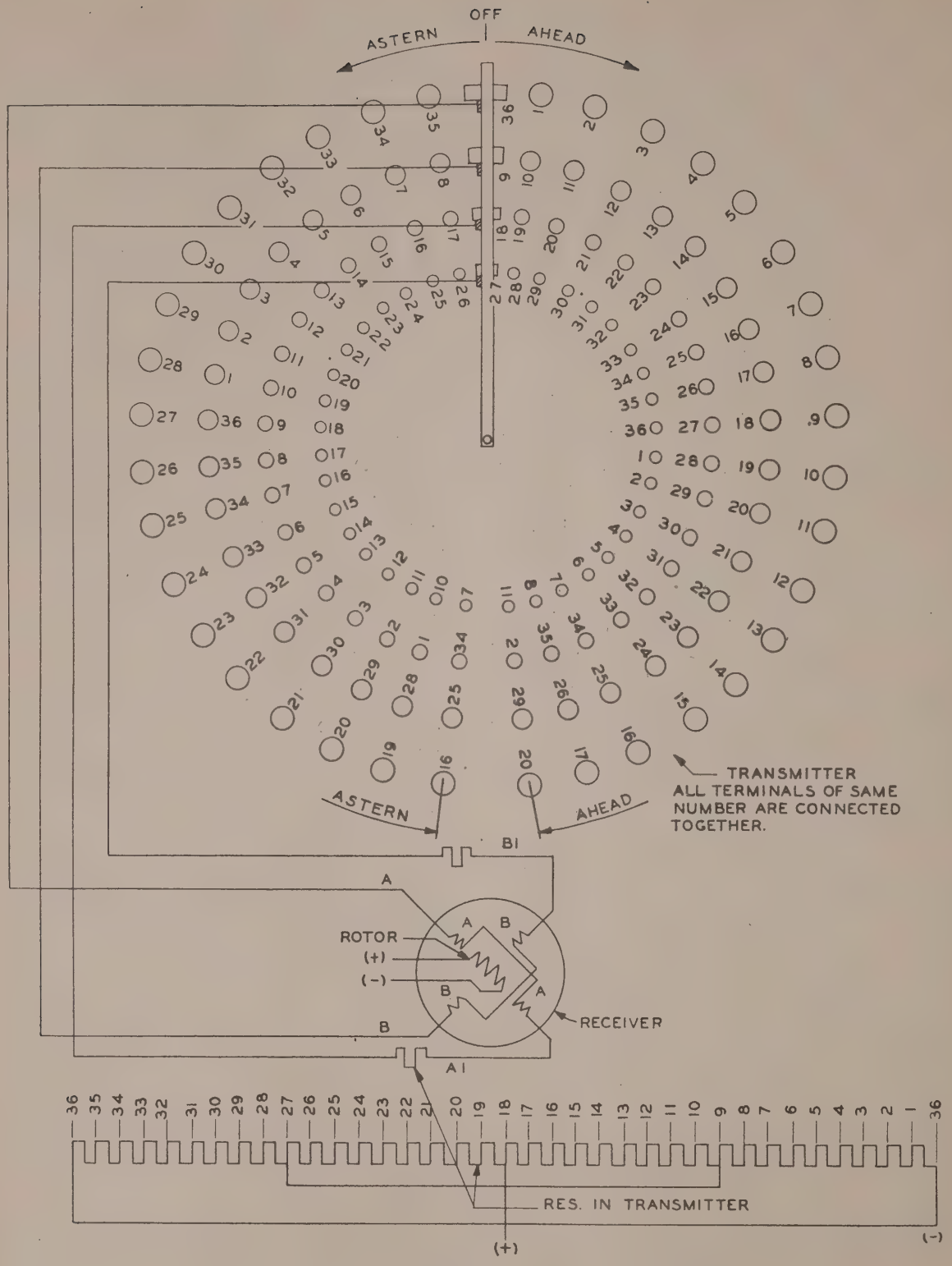


Fig. 12X
Main Positioning System

progressive step, the current in winding A is decreased and the current in winding B is increased in a direction from B to B1. When step 9-18-27-36 (reading from outside toward the center) is reached, winding A is at zero voltage and winding B has full voltage impressed upon it and the rotor has then moved to a position coincident with winding B. Owing to the special design of the resistance steps and arrangement of the stator winding, together with the rotor design, there are corresponding intermediate positions of equal torque as the transmitter brush arm moves over the stationary segments.

Further movement of the brush arm causes the current to decrease in winding B and increase in winding A. However, the current in winding A will be in a direction reversed from its previous direction before arriving at step 9-18-27-36. When the brush arm reaches step 17-26-35-8, (reading from outside toward the center) the receiver will have traveled its entire angular distance in the "Ahead" direction or half of its total number of degrees. At the end step 20-29-2-11, (reading from outside toward the center) although the stator pole is shifted, the rotor engages a mechanical stop and hence does not move. Assuming that each step represents a 10 degree shift of the stator magnetic pole axis, the rotor will have moved 170 degrees when step 17-26-35-8 is reached and will have been brought definitely against its mechanical stop when step 20-29-2-11 is reached. Thus, any tendency to lag during intermediate steps is immediately eliminated by the additional torque of the last step. For this reason, although small inaccuracies may be developed between the "Off" and "Full Speed Ahead" positions, the receiver will always reach the full speed ahead position when the handle of the remote control transmitter reaches the "Full Speed Ahead" position. Inaccuracy at the "Off" position is always taken care of in the generator field controller.

When the brush arm is moved from the "Off" position in the "Astern" direction, resistance is inserted into the circuit of winding B. Thus, through each progressive step as in the "Ahead" direction, the current in winding A is decreased and the current in winding B is decreased. However, the direction of the current in winding B will be in the opposite direction for "Astern" operation, that is, in a direction from B1 to B, and consequently the receiver will rotate in a direction opposite to that for the "Ahead" direction. When step 27-36-9-18 (reading from outside toward the center) is reached, winding A is at zero voltage and winding B has full voltage impressed upon it and the rotor has then moved to a position coincident with winding B but 180 degrees out of phase with the corresponding position for the "Ahead" range due to the fact that the current in winding B is reversed from that in the "Ahead" range. When the brush arm reaches step 19-28-1-10 (reading from outside toward the center), the receiver will have traveled its entire angular distance in the "Astern" direction or the remaining half of its total number of degrees. At the end step 16-25-34-7 (reading from outside toward the center), although the stator pole is shifted, the rotor engages a mechanical stop and hence does not move.

Direction of Receiver Rotation

If, after installation, the receiver runs opposite to the desired direction, that is, if the direction of receiver rotation, as indicated by the speed controller escutcheon plate, does not correspond with the direction of operation of the handle of the remote control transmitter, the correction can be made by interchanging leads A and A1 or leads B and B1.

TYPE D MULTIPOLE CONTACTORS

See Fig. 13X

The type D line of contactors comprises numerous assemblies of standard sizes of contacts, links, magnets, coils, etc. Poles and magnets of different sizes and ratings may be combined to make up a required assembly. Combinations with over-lapping normally open and normally closed poles with or without blowouts and with one or more magnets are obtainable. Normally open and normally closed poles of the same rating are made up of the same parts assembled in the required relation to one another. Latched type contactors with remote or manual reset are also available.

All contacts break vertically and are in front to provide maximum accessibility, so that contacts may be dressed or renewed without interfering with other parts. All copper shunts are made of the highest flexibility material obtainable and they are arranged to require very small movement, thus providing long life.

To remove a magnet coil, the leads are removed from the terminals, the plunger is disconnected at the top, the name plate bracket is removed and the

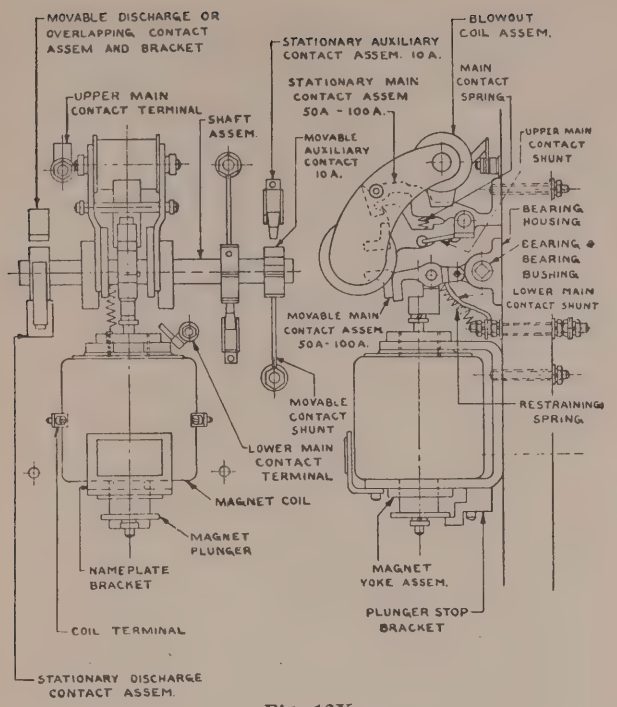


Fig. 13X
Type D Contactor

two large core nuts at top and bottom unscrewed. The coil may then be pulled out. The top core nut is permanently dowelled to the upper core and these two parts should never be separated because their relation determines the proper air gap between the top core and the plunger as set at the factory. It is not necessary to remove the magnet from the panel in order to remove the coil.

When the plunger is replaced, it should be located by means of the locknuts on the plunger shaft, so that the main contacts have a gap of approximately $\frac{7}{16}$ inch. As the contacts wear, the pressure may be restored by using this adjustment of the plunger, thus avoiding loss of contact pressure with wear of the contacts. The contacts should of course be replaced after they wear about $\frac{1}{16}$ inch on each contact.

Field discharge or "Overlapping" contacts have a gap setting of from $\frac{3}{8}$ inch to $\frac{7}{16}$ inch. The important consideration in setting discharge contacts is to insure that they open after the main contacts close. Such contacts may be with or without blowout as required.

Magnets are in four sizes, A, B, C and D. The contact sizes are, 10 A., 25-50 A., 100 A., 150 A. and 300 A. The 25 and 50 A. ratings refer to the same assemblies except that the contact spring is stronger for the 50 A. rating, thus, more 25 A. than 50 A. contacts may be operated from a given magnet size. The magnet size, or number of magnets, is determined by the number of contacts and the strength of the contact springs. All sizes of contactors may be made up in numerous combinations of poles and magnets of different sizes. For example, size D magnets may be assembled with 10 A., 25-50 A., 100 A. and 150-300 A. contact assemblies, with or without discharge contact assemblies, blowouts, etc., and arranged according to the requirements of a given application.

Maintenance. Size D contactors are provided with sealed ball bearings and hence do not require any lubrication. Size A, B and C contactors have sleeve bearings and consequently it is desirable to occasionally oil the bearings on these sizes. Oil will prolong the usefulness of these bearings but where it aggravates the deposit of dirt, its use should be very limited or possibly avoided. It should be kept in mind that too much oil can be damaging as well as not enough oil. In no case should oil get on the contacts.

Periodic cleaning of the parts will promote the most satisfactory service. Care must be taken in using air pressure for cleaning as too much air pressure will cause damage to the flexible shunts. Cleaning with a brush is preferred to the use of air pressure.

TYPE EE CONTACTOR
Single Pole Direct Current— 300 Amperes, 600 Volt

The type EE contactor is a general purpose, heavy duty, improved "Clapper" type with pressed steel frame. It may be used with or without blowout coils and arc shutes and with or without any required and reasonable number of interlock contacts in various combinations. All parts subject to rust are cadmium plated.

Referring to Fig. 14X, the armature assembly (2) is hinged to the magnet bracket (1) by the use of special machining of the parts. In this manner wear of the bearing really improves the magnetic circuit rather than being detrimental.

In the open position, the lever of the armature assembly strides an adjustable stop bolt in the magnet bracket. Positive opening is insured by the strong spring (22.) The main contacts have a

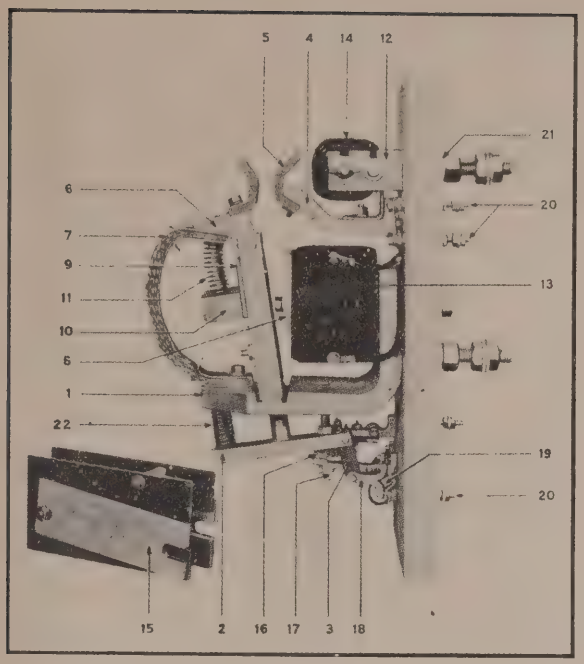


Fig. 14X
Type EE Contactor, Blowout Removed

definite wiping action due to the turning of the movable contact support (6) of the armature assembly. Both the stationary and the movable contacts (5) are identical and are readily replaceable.

Current is carried from the movable contact through the flexible connector (7) to the magnet bracket and then through the panel by the movable contact terminal stud (24). Current is carried to the upper contact through the blowout coil terminal stud (21), the blowout coil bracket (12), the blowout coil (14) and the stationary contact assembly (4).

The magnet coil (13) is of the "Doughnut" type with Class A insulation, completely impreganted with oil proof compound. This coil is slipped over the core of the magnet bracket (1) and is held in place by a capscrew and pole shoe (8). The lever shaft fits into the armature and is held in place by a taper screw. The end of this shaft is split so as to expand and fit tightly into the armature. To remove the coil, it is necessary to remove the shaft and armature assembly.

The blowout assembly consists of blowout coil and core (14), the bracket (12) and arc box assembly (15) with wing nuts. The blowout coil bracket (12) supports the blowout coil and also provides a terminal. The arc box may be readily removed by loosening the wingnuts and pulling it outward. The holes for the wing nuts are slotted to permit this.

The interlocks are composed of operating lever (18), stationary contact assembly (16), movable contact assembly (17), bearing supports, bearing bushings and shaft (19). The operating lever (18) is connected to the lower lever of the armature assembly (2) by link (3). Single pole normally closed interlocks of the heavy duty type are shown. The interlocks are identical with parts of the Type D line of contactors described on other sheets. For heavier breaking duty, they may be provided with blowouts where desired and used for 50 ampere circuits. 10 ampere interlocks are also available. For further description refer to instructions on Type D contactors.

Maintenance. Periodic cleaning of the parts contributes to longer life. Where severe service is encountered, it is advisable to dress the main contacts occassionally with a file. When the contacts wear more than approximately $\frac{3}{32}$ inch on each contact, they should be replaced because the pressure becomes too low for carrying the rated current.

The use of a few drops of light machine oil on the various bearings will promote trouble-free operation.

PUSH BUTTON SWITCHES (10 AMPERE)

See Fig. 33X

The 10 ampere push button switch may be either single pole or double pole and may be either manual return or spring return to its normal (pulled out) position. For the single pole switch the contacts may be either normally open or normally closed. The various combinations of contacts for the double pole switch are: (1) Two sets of normally open contacts, (2) Two sets of normally closed contacts or (3) One set of normally closed contacts and one set of normally open contacts.

The movable contacts consist of copper bars mounted between and clamped by square blocks of insulating material. The movable contacts may be replaced by loosening the clamping screw at the rear of the operating shaft. When a set of contacts is closed, the copper bar shunts two adjacent stationary contact fingers. The stationary contact assemblies are mounted on a square tube of insulating material and each contact assembly contains an individual spring for contact pressure. This spring

may be removed from its stirrup without disassembling any part of the unit.

Maintenance. The stationary contact fingers and movable contact bars on these push button switches should be examined periodically for wear and cleaned when necessary. Contacts should be replaced when the wear is about $\frac{1}{32}$ inch.

Use no lubricants.

PUSH BUTTON SWITCHES (30 AMPERES)

See Fig. 34X

The 30 ampere push button switch may be either single pole or double pole. The single pole or double switch may be manually operated to the open or closed position or it may be manually operated to the open position and spring return to the closed position. The double pole switch is in reality two single pole switches mounted back-to-back with a tie bar connecting the two movable switch plugs together and thus causing them to act as a unit.

The stationary contacts are hard drawn copper and are mounted on pivoted contact arms. The pivot bracket and terminal stud is mounted on a panel of insulating material which in turn is mounted on an "L" shaped base. Individual springs under each stationary contact arm provide the contact pressure and these springs are replaced by removing the arm. The movable contacts are also of hard drawn copper and are mounted on a block of insulating material. They are replaced by removing, from the operating shaft, the unit consisting of the movable contact and the insulating block. When a set of contacts is closed, the movable contact shunts two adjacent stationary contacts.

Maintenance. The contacts on these push button switches should be examined periodically for wear and should be replaced when the maximum wear on each contact becomes $\frac{1}{32}$ inch.

Use no lubricants.

ROTARY SWITCHES (10 AMPERES)

See Fig. 35X

The 10 ampere rotary switches are made up for any number of poles. The movable contacts are mounted on a square insulated shaft and may or may not be electrically insulated from each other, depending upon the desired circuit connections. Thus, the movable contacts set up the desired circuits for a definite position of the switch and may complete circuits across various numbers of stationary contacts. Also, a continuous circuit may be maintained across two or more stationary fingers for a number of positions of the switch by the use of movable contact rings.

The stationary contact fingers are made of phosphor-bronze and the stationary contact finger supports are mounted on a base of insulating material. A spring is used to provide the contact pressure and this spring may be removed from its stirrup without disassembling any part of the unit. External connections are made at the stationary contact finger support through the terminal studs.

These switches usually have an even number of poles. However, an odd number of poles are provided by omitting the last set of contacts in the rear of the switch and providing a longer non-conductive spacer at the rear of the operating shaft.

The rotary switch is held in each position by means of the positioning guide, positioning ball and positioning spring. The positioning guide is mounted on the operating shaft and has several conical shaped detent holes, the number of detent holes being equal to the number of switch positions. The positioning spring causes the positioning ball to enter a detent hole to hold the switch in the desired position.

Maintenance. The contact fingers should be examined periodically for wear and cleaned when necessary. Contact fingers should be replaced when the wear is about $\frac{1}{32}$ inch.

Use no lubricants.

ROTARY SWITCHES—TYPE "W"

The rotary switch may be made up for any number of circuits. The movable contacts are mounted on an insulated shaft and may or may not be electrically insulated from each other, depending upon the desired circuit connections. The movable contacts may provide a circuit for a definite position of the switch. Also, a continuous circuit may be had by the use of contact rings for a number of positions of the switch as may be desired. The movable contacts may complete a circuit across various numbers of stationary contacts.

The stationary contacts are mounted on a base of insulating material. A spring is used to provide

the contact pressure. External connections are made at the stationary arms through the terminals at the bottom of the switch.

Two fingers exerting pressure on notches in a positioning cam, determine the various switch positions.

Maintenance. The contact fingers of the stationary contacts should be examined periodically for wear and cleaned when necessary.

Use no lubricants.

GENERATOR CUT-OUT SWITCH

See Fig. 36X

The generator cut-out switch is a two position switch. The switch is locked in either position by a locking lever pin. To move the switch from one position to the other, the release knob must be turned to disengage the locking lever pin from the operating shaft.

The switch is operated by a long operating handle that is connected to the operating shaft which in turn is supported on self-aligning ball bearings. The movable main contacts are tightly clamped to the insulated portion of the operating shaft and turned down to size. These contacts engage the stationary main contact assemblies which are mounted on insulated cylindrical bars. Terminals are provided for external connections. The stationary contacts may be removed one at a time without removing the complete assembly from the insulated bars. To remove a stationary contact, remove the bolt holding the flexible lead and then remove the bolt holding the contact pressure spring and the stationary contact is then free to be removed. Note will be taken of the stationary contact arrangement which is such that heavy overload currents will tend to press the stationary contacts more tightly onto the movable contacts due to the magnetic field set up as current travels around the loop formed by the flexible leads.

On the rear end plate are mounted two sets of auxiliary contacts. These are so arranged that one set of contacts is closed in each position of the switch, that is, in the "By-pass" position, one set of contacts is normally closed and the other set is normally open. The movable contact is a copper bar which shunts two adjacent stationary fingers when a circuit is closed.

On the front end plate is mounted the locking device and latch contacts. The locking lever has a pin at one end and this pin engages openings in the operating shaft, thus locking the operating shaft in each position. The other end of the locking lever is connected to the release shaft. The locking lever is held in the position for locking the operating shaft by means of the locking lever tension spring, and to free the switch for movement, the release knob must be turned against the action of the locking lever spring. On the release shaft is mounted the movable latch contact. The latch contacts are closed when the operating shaft is locked in position and open when the operating shaft has been released for movement.

Maintenance. Approximately once in six months, a good grade of light cup grease should be applied to the pressure fittings. Care must be taken so that too much grease is not applied, because this will cause excessive pressure against the gasket seals of the ball bearings and hence possibly cause them to leak. Reasonable caution should thus be exercised. Use a *small* amount of vaseline on the movable main contacts to keep them lubricated.

The auxiliary contacts and latch contacts should be inspected periodically and cleaned when necessary.

TYPE "D" CURRENT LIMITING DEVICE

See Figs. 15X and 16X

Description. The type "D" current limiting device is a simple intermittent duty unit for heavy duty service. It is used for limiting the current of generators and motors where momentary heavy surges would otherwise exist.

It consists of a relay element and a contactor element as shown in Fig. 15X. The relay element CLD has its current coil in series with the machine leads and its normally open contacts operate the contactor magnet. A condenser and resistor reduce sparking of contacts. The contactor element CLDX has its main contacts (normally closed) connected across an adjustable resistor which is in series with the generator field circuit. This may be traced in Fig. 16X. An indicating lamp when used, is energized when normally open auxiliary contacts of the contactor close.

Operation. When the current rises in the generator leads to the set-pick-up value of the relay element CLD, the contacts of CLD close, completing the

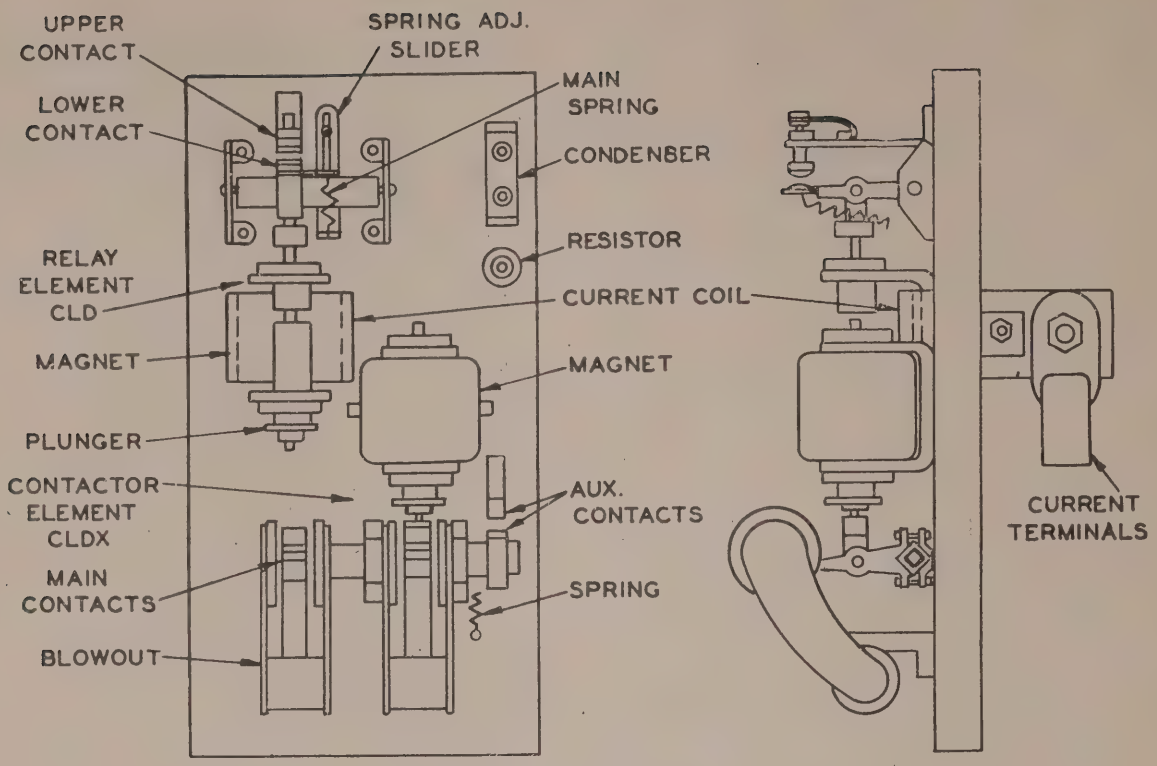


Fig. 15X
Current Limiting Device

coil circuit of CLDX from positive to negative of the control circuit. The energizing of the coil of CLDX causes opening of its main (normally closed) contacts and the insertion of the field reducing resistance in the generator field circuit. Inserting this resistance in the field circuit causes the generator voltage and therefore the armature current to be reduced, causing the relay element contacts to open with consequent reclosing of the contactor element contacts. If the conditions causing the overcurrent condition still exist, the cycle is undergone again and again. That is, the device vibrates until normal conditions are restored and it comes to rest. The effect is to hold an average current in the circuit.

Settings. The principal setting of this device is the main spring of the relay element. Moving the slider which holds the spring downward increases the spring tension and therefore the current setting. Moving it upward has the opposite effect.

The contactor element has no settings which will affect the calibration of the device.

The proper adjustment of the field reducing resistance value must be determined by trial. Too high a field reducing resistance will cause too great fluctuations in current, as indicated by an ammeter. Too low a resistance will be noticeable by the inability of the device to limit current properly. The setting of this resistance is not critical but by a few trials a setting will be found which will give the most desirable results.

It must be kept in mind that this is not a device classified as high accuracy. It is not a continuous

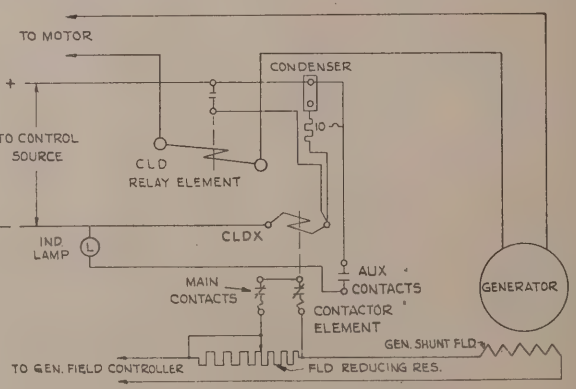


Fig. 16X
Elementary Diagram of
Current Limiting Device

duty current regulator and it is intended only for applications where motors are to be accelerated at intermittent periods and it is desired to limit the maximum current in order to avoid the operation of protective devices which would otherwise shut down the equipment and require re-starting.

In order to reduce the mass and size of the magnet, the coil of the contactor element is of intermittent duty design. For this reason, care must therefore be taken that during preliminary checking and setting, this coil is not left across the line continuously.

Maintenance. Maintenance and wear limits are the same as is given for type "D" multipole contactors. The parts are mostly identical with these heavy duty contactors. Approximately once every 30 days, all contacts should be cleaned and if necessary dressed with a file.

SHORT CIRCUIT PROTECTIVE RELAY

See Fig. 17X

This relay is a simple heavy duty type device employing the same design and parts as the type "D" multipole contactors. It has one normally closed contact. The external connections are made to the terminal studs on the rear of the mounting panel.

The principal setting of this relay is its main spring. When the slider which holds the spring is moved downward the tension on the spring is increased, therefore, increasing the current setting. Moving the slider upwards has the opposite effect. The relay should operate at about 300 per cent of normal full load current of the machines.

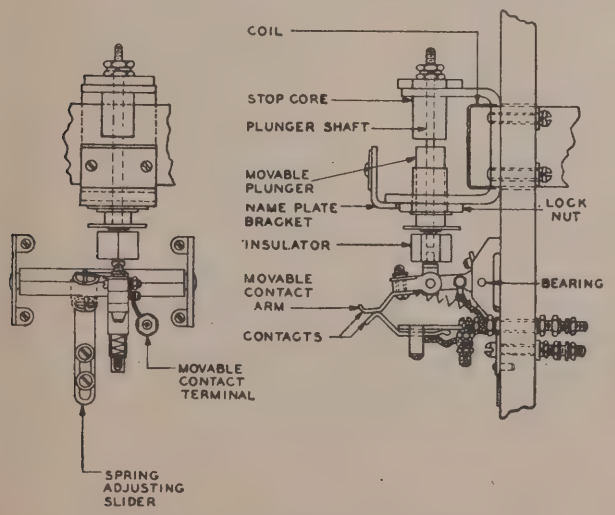


Fig. 17X
Short Circuit Protective Relay

The contacts break vertically and are in front to provide maximum accessibility, so that contacts may be dressed or renewed without interfering with other parts. All copper shunts are made of the highest flexibility material obtainable and they are arranged to require very small movement, thus providing long life.

Maintenance. Since this device is seldom operated, little attention is required. Accumulation of dust and dirt should be removed and a drop of oil applied on the bearing surfaces occasionally. Periodic cleaning of the parts will promote the most satisfactory service.

TYPE "R-250" VOLTAGE REGULATORS

Description. This voltage regulator is a specially applied motor operated rheostat with features providing for fast voltage recovery, high sensitivity, broad range, few wearing parts, ruggedness and virtual immunity to shock and vibration. It is especially suited to transportation equipment, as for railway and shipboard. All moving parts are protected from dust.

Referring to Figs. 18X and 19X the parts are grouped into several assemblies as follows:

31—Torque motor
16—Actuating shaft assembly
12—Main shaft assembly
17—Dashpot assembly
8—Sector assembly
3—Resistor bracket and commutator assembly
2—Front cover assembly
30—Rear cover

The torque motor windings are connected to the main leads of the generator being controlled. Its shaft extends through the panel (1) and operates the actuating shaft assembly (16) in tandem. The actuating shaft assembly operates the air dashpot piston by means of a flexible "Recall" spring coupling and also the main shaft assembly (12) through a connecting link (14.) The main shaft assembly operates the sectors which roll over the stationary commutator segments to cut resistance in and out of the shunt field circuit as required to maintain constant voltage. By this method a very

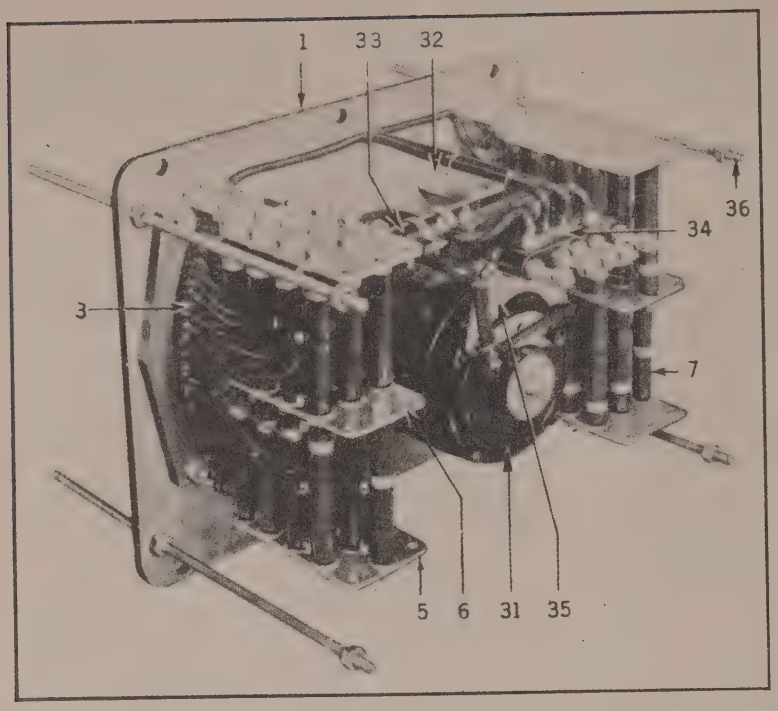


Fig. 18X
Type R-250 Voltage Regulator—Rear View

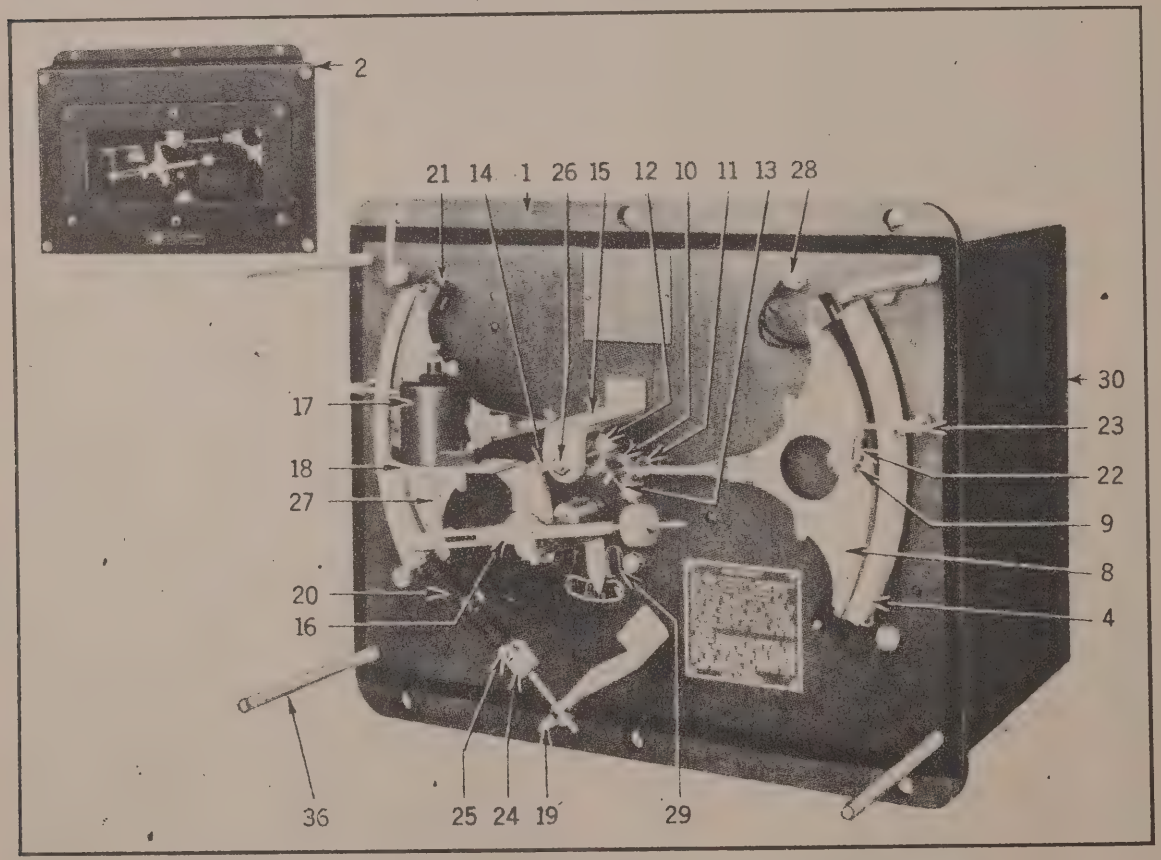
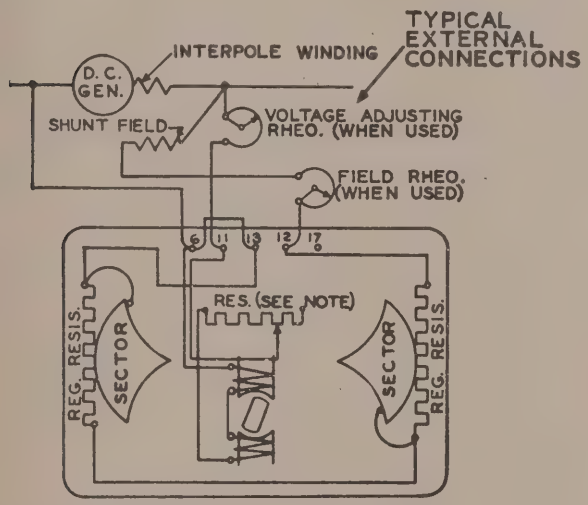


Fig. 19X
Type R-250 Voltage Regulator—Front View

small movement of the torque motor armature is multiplied into a much greater movement of the contact sector, with consequent rapid changes in shunt field resistance.

The electrical connections are shown on Fig. 20X. The generator shunt field is connected in series with the regulator resistors through terminals (12) and (13). The torque motor is connected to the generator leads by means of terminals (6) and (11). Permanent resistance (33) is always used in series with the torque motor but not always in series with the generator field circuit. In any case, all resistance is mounted inside the rear cover. Fine changes in regulated voltage are made by means of the slider on the torque motor resistor, as given later, or by means of a voltage adjusting rheostat which may or may not be mounted inside the regulator case.

Operating Principle. In operation the torque motor armature will tend to change position with a change in voltage of the generator since it is restrained by the main spring (20). The motor torque and main spring settings are adjusted at the factory so that the same voltage is required to balance the armature against the counter torque



NOTE:
1) 1-75 OHM-110 WATT. RESISTOR FOR 75V. REG. IN SERIES WITH TORQUE MOTOR. 1-ADJUSTING LUG.

2) 2-75 OHM-110 WATT RESISTOR FOR 120/125V. REG. IN SERIES WITH TORQUE MOTOR 1-ADJUSTING LUG.

3) 2-100 OHM-100 WATT RESISTOR FOR 220/250V. REG. IN SERIES WITH TORQUE MOTOR 1-ADJUSTING LUG

Fig. 20X
Schematic Diagram of Voltage Regulator, Type R-250

of the main spring for any armature position, thus if external conditions, such as generator speed, load or internal shunt field resistance due to temperature, cause a change of torque on the regulator motor armature, the armature will move the sectors in such a direction as to cut in or out shunt field resistance and re-establish the set voltage at a new position of the armature. It is for this reason that the setting of the main spring must not be altered from its factory setting unless it has been definitely determined that the armature does not balance at the same voltage for every position. Any change from this "Flat" characteristic of the armature will cause a corresponding error in voltage at different speeds and loads of the generator. A new main spring should be used in preference to changing the factory settings.

As the actuating shaft assembly moves, the "Recall" spring causes movement of the dashpot piston almost independently of the actuating shaft or torque motor armature, thus for demands for quick changes of field resistance, the sectors move to new positions and the dashpot piston follows an interval later. This is the anti-hunting feature of the regulator; it makes the restraining effect on the actuating shaft proportional to the error in voltage and prevents over-travel of the sectors with resulting objectionable swings of voltage, at the same time allowing rapid restoration of voltage after a change occurs. The anti-hunting characteristic is adjusted by means of the slider on the lever (16) and the needle valve on the dashpot, as described later under "Adjustments."

The stops (29) limit the travel of the torque motor armature. A pointer moves over a scale to indicate the relative amount of resistance connected into circuit by the sectors. The "0" point of the scale indicates resistance "All Out" and the "4" point indicates resistance "All In." The intermediate points 1-2-3 are simply for reference and indicate no special values.

The Torque Motor (31). The torque motor is a series type with ball bearings. It is entirely protected so as to exclude foreign matter. Owing to the very short air gap, it permits operations at approximately ¾ ampere. The ball bearings need no attention except the use of very light machine oil approximately every six months. The oil holes are above each motor bearing. The purpose of the oil is to prevent possible rust.

The Actuating Shaft Assembly (16). The dashpot piston is connected to the clevis on the end of the recall spring. The recall spring is connected rigidly to the actuating shaft by means of screws. The slider forms a fulcrum point for the recall spring and enables adjustment for stiffness and hence anti-hunting characteristic of the moving system. The slider moves in a slot and is locked in position by a nut and lockwasher.

The extension of the torque motor shaft is locked in place by a taper dowel. In case of replacement of a torque motor, the dowel hole in the motor shaft must be drilled and reamed in the new shaft.

The counterweight, consisting of calibrating washers, is fixed in position at the factory so as to make the moving system statically balanced and allow constant voltage to be maintained during all positions of the complete regulator and during movement and jolting of the mounting. The pointer has been explained under "Operating Principle" above. The main spring (20) connects to the bearing yoke (24) and pivot (25).

Main Shaft Assembly. Levers (11) support the hardened steel sector bearings on one end and the other ends are forced toward the shaft by compression springs (13) thus the sectors are forced outward from the shaft against their respective "Commutators." Bearings on the hub form fulcrum points for the levers. The hub and shaft are fastened together by a dowel. The shaft is pointed and hardened at each end to operate in hardened steel sockets (26).

A drop lever is dovetailed into the hub rigidly as shown so that it moves with the shaft and it carries a bracket which in turn supports a bearing for connecting link (14). Connecting link (14) fastens to the actuating shaft assembly as shown.

The Air Dashpot Assembly (17). The dashpot assembly is composed of a special bakelite-graphite composition cylinder and a piston of similar material, together with a needle valve and locknut for adjustment. The piston is connected to the recall spring clevis by means of piston extension shaft (27). There is a bearing at the piston and at the recall spring clevis. The cylinder is mounted with the open end down to prevent accumulation of foreign matter.

The Sector Assembly (8). The carbon rim is accurately machined so as to make positive contact on every segment of the commutator (4). The rim is removable and no attempt should be made to remachine it when it wears because this would shorten the radius and prevent making contact on the end steps. Use a new carbon rim when wear is noticed. Leads connect the sector to the stationary terminal (28). The sector is connected to its arm by an insulating connector and rivets. The sector arm is slotted for a bearing and highly polished to reduce friction. The sector is easily removable by removing the guides (21).

Resistor Bracket and Commutator Assembly (3). The commutator and resistors are an integral unit as illustrated. The commutator is composed of hard drawn copper segments secured into the frame and insulated with mica. The commutator segments are grooved to act as guides and contacts for the sector carbon rim and are heavily silver plated and polished. The resistance tubes (7) are supported in a metal frame which is in turn supported from the commutator. The complete assembly is removable from the regulator by removing the screws and dowels in front.

The resistors connect to the commutator segments by asbestos insulated flexible leads.

If a commutator is replaced, it is necessary to accurately center it to the center of the main shaft bearings (26) and then drill and ream for the dowel pins. Commutator replacements will not be required if care is taken to keep them clean, and to see that they are not overloaded. Sparking usually indicates the presence of dirt on the contact track.

Front Cover (2). The front cover is composed of sheet steel with a removable glass window for inspection. The glass is readily renewable in case of breakage and is sealed with a felt gasket. The complete cover is pressed against a gasket on the panel and is held by four nuts on studs (36), thus protecting the moving parts from foreign matter. For routine inspection, only the front frame need be removed. The cover is in two parts, as illustrated.

Rear Cover (30). The rear cover when used is of perforated sheet steel and is held in place by the four nuts on studs (36). There is a slot provided for the terminal block (34) and terminal studs. The terminal block is not fastened to the rear cover; it is supported from the torque motor frame by a bracket.

Adjustments. There are only three adjustments required or that should ever be attempted, unless it has been definitely determined that there are other

reasons for troubles that may arise. They are the dashpot slider, the dashpot needle valve and the voltage adjusting resistor (33) (or voltage adjusting rheostat, when used).

When a regulator is mounted and ready for service, all strings used for holding the parts in place should be removed and the mechanism moved by hand to insure that there are no damaged parts. Use care when cutting the strings and do not allow the moving assembly to slam against the stops. With this done, the dashpot slider or "Recall" spring slider should be set at approximately the center of its travel and clamped there with the nut. The needle valve should be set so that the dashpot gives appreciable retardation to the torque motor shaft when it is moved over its total travel. The generator should then be started with the regulator connected in circuit and the operation observed. Alter the slider and needle valve settings until the most rapid response with minimum over-travel is obtained. Do not move the lever by pressing on the counterweights; this may bend the small counterweight stud.

If the voltage tends to fluctuate above and below the setting at a constant period, "Hunting" is present and should be corrected by closing the needle valve slightly. If the voltage recovers too slowly when a change in speed or load occurs, move the slider toward the main shaft to obtain more flexibility of the recall spring.

If the application is for holding constant voltage while the generator speed varies over considerable range, it will be found that the proper settings are for a relatively stiff recall spring and weak damping on the dashpot, while if the application is to hold constant voltage with the generator load varying over considerable range, the speed remaining approximately constant, the recall spring will be weak and the dashpot relatively strong. For small machines with inherently quick response, only very slight dashpot action is needed.

For resetting the value of voltage to be held constant, the resistor (33), (or the voltage adjusting rheostat, when used) in series with the torque motor, should be adjusted. Increasing the resistance will cause higher regulated voltage while decreasing it will cause lower voltage. This is the *only* voltage adjustment; *no springs or other parts* should be moved because that will cause errors in voltage regulation for different positions of the torque motor armature, as explained in Article 2, "Operating Principle."

It must be kept in mind when making settings for voltage that the regulator has been designed for a given range of adjustment according to the application and good operation might be sacrificed if it is attempted to operate outside this range; also before operating the regulator with a given machine, be sure that the machine characteristics, especially field resistance and current are of a rating within the range of the regulator. There is a name plate

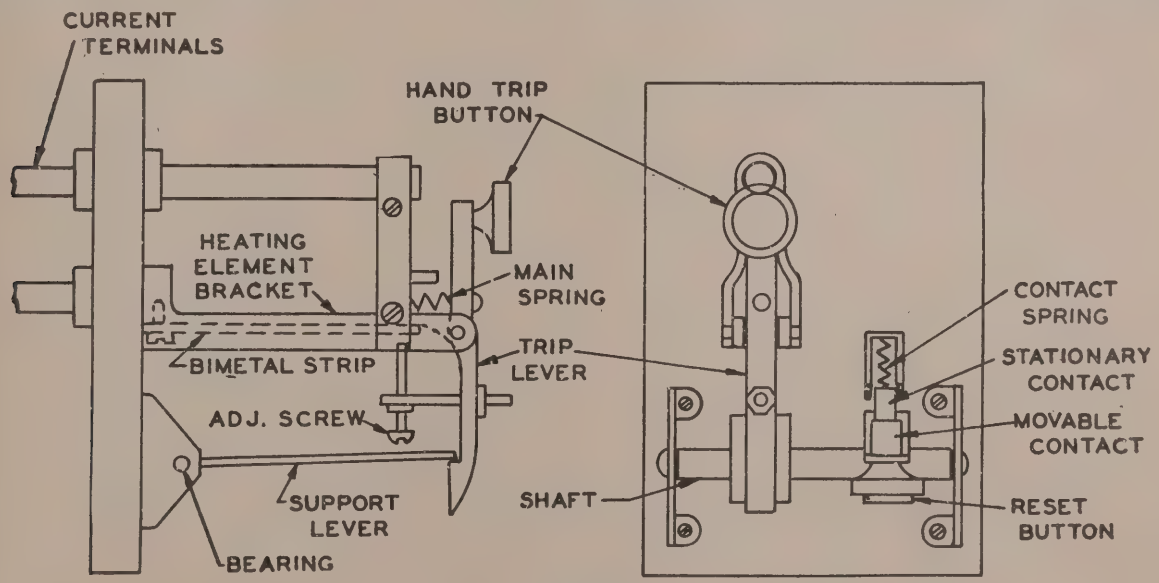


Fig. 21X
Type TH Thermal Overload Relay

on the regulator giving its voltage range and resistance.

Maintenance. The only maintenance required is that of cleaning the commutators, oiling the sector bearings (at lever 11) and oiling the torque motor bearings. The commutator grooves should be cleaned at least once a month, using a soft cloth, or a pencil eraser if discoloration is not easily removable with a cloth. In no case should abrasives be used because that would destroy the silver plating. Avoid oil on the commutator because it causes sparking and deterioration of both the sector and the commutator. If dirt and oil are kept off the commutators, destructive sparking will be avoided and thus replacements are seldom required.

The sector carbon rims are renewable for cases of breakage or wear. Sparking will cause rapid wear and for that reason when such is observed, the commutators and sectors should be immediately cleaned.

The sector bearings require one drop of oil each approximately once in two months. This is to reduce wear and friction which cause voltage errors. The torque motor ball bearings should be oiled once in six months. Use very light machine oil (similar to sewing machine oil) for both the sector and torque motor bearings. Use the oil sparingly to avoid accumulating dust.

Do not attempt to alter the settings of the sector pressure springs (13) unless the pressure is obviously out of adjustment. These have been set at the factory for proper contact pressure and minimum mechanical wear of the carbon rims and bearings. The total pressure on a sector should be approximately (6) ounces.

Check the dashpot periodically to be sure it is free of dirt which might cause friction. Clean with a cloth if necessary.

TYPE "TH" THERMAL OVERLOAD RELAY

Description. The type "TH" thermal overload relay is a simple hand reset device for the protection of electrical machines. It allows the addition of various attachments which form other types. It has an inverse time limit characteristic. That is, the greater the current the less the time required for operation. The relay may be made up of one or more elements depending upon the number of circuits to be protected. That is, a device for the protection of both the positive and the negative sides of a direct current circuit will have two elements acting upon one trip lever. Provision is made for hand tripping as well as hand resetting. Normally open or normally closed contacts, or both may be provided. The contact capacity is three amperes.

Fig. 21X shows a two element type "TH" relay for circuits of over 100 amperes. The heating element bracket contains the bimetal thermostatic strip which is fastened at the end next to the base and is free at the outer end. The two terminals are connected in the line to be protected so that current passes through the heating element bracket.

Under normal load conditions, there will not be enough heat generated to cause the bimetal strip to bend downward sufficiently to engage the adjusting screw but when an overload occurs, the bending is enough to press the adjusting screw downward, forcing the trip lever outward and allowing the support lever to drop downward.

Since both the support lever and the movable contact support are fastened rigidly to the shaft, the dropping of the support lever causes opening of the contacts and thus opening of whatever switch the relay controls.

Hand resetting is accomplished by pressing upward on the insulated reset button, fastened to the

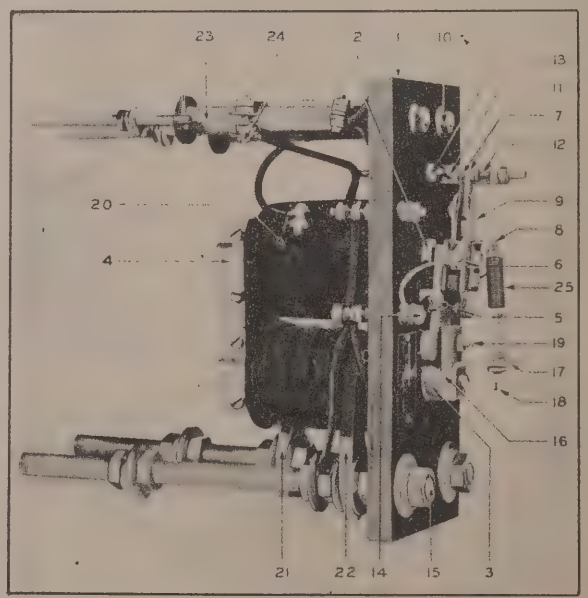


Fig. 22X
Type FS Reverse Current Relay

movable contact support, until the trip lever engages the support lever. Before the relay can be reset, a short time must elapse to allow cooling of the heating element.

This type of relay must be mounted so that the contacts open vertically. It should not be placed where there is appreciable air draft, otherwise its operation may not be consistent. Being a thermostatic device, it must not be placed where it might be influenced by heat from resistors or heaters.

Adjustments. The only adjustment is the adjusting screw. Screwing this downward increases the current at which the relay will operate. This allows adjustment over a range of approximately 40 per cent of the rating of the relay.

When checking after an adjustment, it must be remembered that the overcurrent condition must be maintained for from several minutes to one quarter hour or more before operation will occur. On heavy over currents, operation will be within several seconds.

For cases where supplementary short circuit protection is desired, an extra attachment is provided above the heating element bracket. An electrical reset device as well as automatic reset can also be attached.

Owing to different ambient temperatures, factory settings may not be accurate. For this reason it is well to test for operation at the desired current after installation.

Maintenance. The only maintenance is that of keeping the parts clean. The presence of dirt may affect the reliability of the relay. No oiling of any part is advisable.

TYPE "FS" REVERSE CURRENT RELAY

The type "FS" relay is a simple control device for direct current service using current and voltage coils. Normally when the relay is connected in circuit, as in connection diagram, Fig. 23X, and the current is flowing in the proper direction, the current coil assists the voltage coil in holding the main contacts closed but when current reverses the ampere turns of the current circuit subtract from those of the voltage circuit and the relay contacts open at a predetermined value due to spring (25) causing opening of the power circuit. (Fig. 22X.)

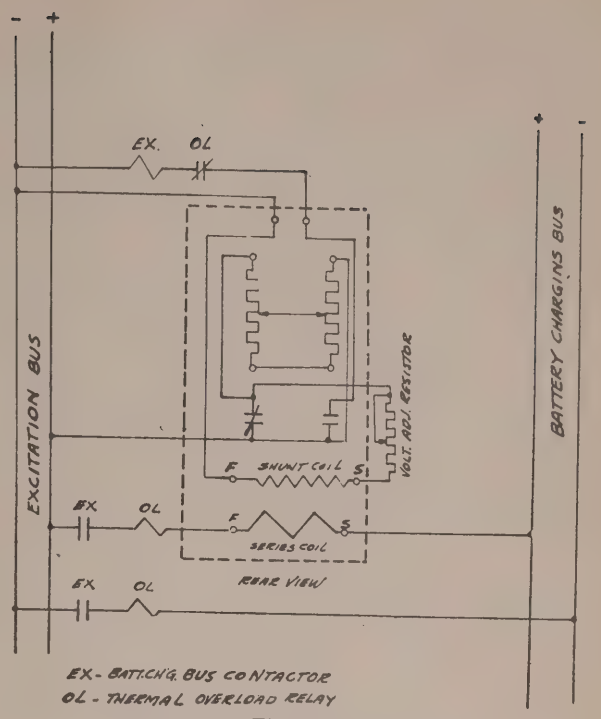


Fig. 23X
Type FS Reverse Current Relay—Connection Diagram

The voltage coil strength is of such value as to cause re-closing of the relay contacts when the voltage returns to a predetermined value, although the current circuit will be de-energized due to the power circuit being open.

Referring to Fig. 22X and connection diagram Fig. 23X the current and voltage coils are wound on a common magnetic circuit 2-3-4-5. The current circuit terminates at the two large studs (15) at the bottom and the voltage circuit terminates between one of the panel terminals and one of the smaller studs (10) at the top. The other top stud is a terminal for the control circuit. The two adjustable resistors (23) and (24) are in the voltage coil circuit. An additional voltage adjusting resistor for the voltage coil is mounted externally.

The relay has a normally open and a normally closed set of contacts. The movable contacts (7) move with hinged armature (5) and make with stationary front and rear contact studs (12) and (13), respectively. The movable contacts are energized through flexible leads and terminal studs (14). The movement of the contacts and armature is restrained by main tension spring (25).

By connection diagram Fig. 23X, when the relay is in the de-energized position, the voltage circuit is

energized from generator negative, through one of the top studs of the relay, resistor (24) and (23) and the normally closed relay contacts to generator positive. When voltage is sufficient to operate the relay, the normally closed contacts open and insert resistor (23) and (24) which is the intention of the normally closed contacts.

Adjustments. The relay is adjusted at the factory according to the "Pick Up" and "Drop Out" values specified when ordered. Any further adjustments required in the field should be done by means of the variable resistors (23) and (24) and the external adjusting resistor. *No contact gap magnetic air gap, or spring adjustments* should be attempted unless it is found impossible to obtain the required range of operation by means of the resistors. Changing these mechanical values may result in the burning out of voltage coils or continuous vibration of the contacts.

Increasing the resistance of the external resistor makes the relay pick up a higher value, while increasing the resistance of (23) and (24) makes it drop out at a higher value. Too much resistance in (23) and (24) will make the contacts vibrate continuously. Decreasing the resistance of (23) and (24) causes the relay to drop out at a higher value of reverse current.

Maintenance. Maintenance consists of cleaning the contacts as they appear to need it, also all other parts which might accumulate dirt.

No oiling is recommended for any of the parts.

SPARE PARTS

Propulsion and Auxiliary Control

Item No.	*No. of Sets*	*No. per Set*	*Description*	*Catalog No.*
1	5	4	Contact Finger and Lead Assembly (For Current Limiting Device, for Short Circuit Protective Relay, for Field Contactor, for Generator Cut-out Switch, for Main Field Contactor, for Push Button Switch, for Selector Switch, for Starting Contactor (with 1 N.O. & 1 N.C. Interlock), for Pilot Switch, for Voltmeter Switch, for Ground Detector Switch, for Thermal Overload Relay (OL1, OL2, OL3), for Transfer Switch, for 2 P. Contactor (C1, C2).	EG-2532 Pt. 2
2	3	3	Contact Finger (For Short Circuit Protective Relay, for Field Contactor, for Generator Cut-out Switch, for Main Field Contactor, for Selector Switch, for Starting Contactor, for Current Limiting Device, for Thermal Overload Relay (OL1, OL2, OL3), for Transfer Switch, for Contactor (C2), for Contactor (C1), for Thermal Relay).	EG-154807
3	2	4	Contact Tip (For Current Limiting Device, for Field Contactor, for Push Button Reset Switch, for S.P. Contactor, for 1 S.P. Contactor (50 Amp.), for Push Button Switch, for 1 D.P. 50 Amp. Contactor, for Cut-out Switch).	EG-157743 It. 1
4	1	1	Contact Tip and Stem (For Current Limiting Device).	EH-154886 Its. 3 & 14
5	2	3	Contact Strip and Button (For Current Limiting Device, for Starting Contactor).	EH-154848 Its. 3 & 24
6	1	3	Contact Finger (For Generator Cut-out Switch)	EG-153077
7	1	1	Contact Tip (For Main Field Contactor)	EG-154663
8	1	1	Contact (For Reverse Current Relay)	EH-153580 Its. 1 & 2
9	1	1	Contact Tip (For Contactors C1 & C2)	EG-154658 Pt. 3 - It. 11
10	1	2	Contact Bar (For Push Button Switch, for Pilot Switch).	EG-160398 Pt. 2
11	1	2	Contact Piece (For Push Button Switch, for Cut-out Switch).	EG-2258 Pt. 1
12	4	3	Contact Spring (For Current Limiting Device, for Field Contactor, for Generator Cut-out Switch, for Main Field Contactor, for Selector Switch, for Starting Contactor, for Voltmeter Switch, for Ground Detector Switch, for Thermal Overload Relay,	EG-155708

Item No.	No. of Sets	No. per Set	Description	Catalog No.
			for Transfer Switch, for 2P. Contactors C1 & C2, for Thermal Relay).	
13	1	1	Positoning Spring (For Current Limiting Device)...	EG-158378 It. 1
14	1	2	Contact Spring (For Contactors C1 & C2).....	EG-158378 It. 8
15	1	2	Contact Spring..... (For D.P. Contactor 50 Amp., for S.P. Contactor 50 Amp., for Current Limiting Device, for Field Contactor).	EG-158378 It. 2
16	1	2	Contact Spring..... (For Short Circuit Protective Relay, for Thermal Overload Relay).	EH-153594 It. 5
17	1	1	Return Spring (For Current Limiting Device).....	EG-156017 It. 1
18	1	1	Return Spring (For Short Circuit Protective Relay).	EG-156017 It. 2
19	1	1	Return Spring (For Field Contactor).....	EG-154765 It. 1
21	1	1	Contact Spring (For Main Field Contactor).....	EG-158378 It. 6
22	2	2	Contact Spring (For Generator Cut-out Switch).....	ACA-16890
23	1	2	Contact Spring (For Starting Contactor).....	EG-155637
24	1	1	Operating Spring (For Generator Cut-out Switch)...	EG-157565
25	1	3	Compression Spring..... (For Push Button Switch, for Pilot Switch).	EG-2242
26	2	3	Compression Spring..... (For Push Button Switch, for Push Button Switch Reset, for Cut-out Switch).	EG-154170 It. 2
27	1	1	Tension Spring (For Selector Switch).....	EJ-158263 It. 14
28	1	2	Spring..... (For S.P. Contactor, for D.P. Contactor, for Transfer Switch).	EG-154765
29	1	3	Compression Spring..... (For Pilot Switch, for Push Button Switch).	EG-2243
30	1	2	Positioning Spring..... (For Voltmeter Switch, for Ground Detector Switch).	EG-158378 Pt. 14
31	1	1	Return Spring (For Reverse Current Relay).....	EG-148239 It. 1
32	1	2	Arcing Horn (For 2P. Contactors C1 & C2).....	EG-154664
33	1	2	Contact Tip (For 2P. Contactors C1 & C2).....	EJ-159765 Pt. 6 - It. 21
34	1	1	Special Connections (For Governor Transmitter)...	EG-157716 Pt. 1 & 2
35	1	4	Contact Brush (For Governor Transmitter).....	EG-979 Pt. 2
36	1	4	Contact Brush Spring (For Governor Transmitter).	EH-156679 It. 4
37	1	4	Lead (For Governor Transmitter).....	EG-1245 Pt. 1
38	1	1	Capacitor No. X2-G1.....	EK-156008 It. 73
39	1	1	Magnet Coil.....	CRY-59
40	1	1	Magnet Coil.....	CRY-83
41	1	1	Magnet Coil.....	CRY-53

Item No.	*No. of Sets*	*No. per Set*	*Description*	*Catalog No.*
42	1	1	Magnet Coil	CRY-62
43	1	1	Magnet Coil	CRY-50
44	1	5	Indicating Lamp	EG-1017 It. 1
45	1	2	Indicating Lamp Receptacle with Resistor	EG-1017 It. 2
46	1	2	Brushes (For Motor Field Controller)	EG-1493
47	1	2	Spring (R.H.) (For Motor Field Controller)	EG-5970 It. 3
48	1	2	Spring (L.H.) (For Motor Field Controller)	EG-5970 It. 2
49	1	1	Brush Holder (For Motor Field Controller)	EG-5970 It. 1
50	1	2	Resistor, Edgewound 0.25 ohm 60 amp.	EH-1016 It. 5
51	1	2	Resistor, Edgewound 0.33 ohm 50 amp.	EH-1016 It. 4
52	1	2	Resistor, Edgewound 0.50 ohm 40 amp.	EH-1016 It. 3
53	1	2	Resistor, Edgewound 0.15 ohm 75 amp.	EH-1016 It. 13
54	1	1	Resistor, Edgewound 0.75 ohm 30 amp.	EH-1016 It. 2
55	1	1	Resistor, 50 watt, 150 ohms	EH-1015 It. 1
56	1	1	Resistor, 50 watt, 4000 ohms	EH-1015 It. 2
57	1	1	Resistor	EG-159959 It. 1
58	1	1	Resistor	EG-159959 It. 2
59	1	1	Resistor	EG-159959 It. 3
60	1	1	Resistor, 100 watt, 500 ohms	EH-1014 It. 2
61	1	1	Resistor, 1 ohm, 30 amp.	EH-1016 It. 14
62	1	1	Resistor, 40 ohms, 2.1 amp.	EH-1016 It. 6
63				
64	1	16	Fuses N.E.C. 3 amp. 600 volt	
65	2	4	Fuses N.E.C. 50 amp. 250 volt	

For Voltage Regulator

66	1	1	Main Spring	EG-154611
67	1	1	Sector Spring	EG-154609
68	1	1	Spring (For Shaft Assembly)	EG-153759 It. 6
69	1	1	Stop Spring	EG-155519
70	1	1	Resistor, 0.25 ohm	EJ-154615 It. 14
71	1	1	Resistor, 0.32 ohm	EJ-154615 It. 15
72	1	1	Resistor, 0.40 ohm	EJ-154615 It. 16
73	1	1	Resistor, 0.50 ohm	EJ-154615 It. 17
74	1	1	Resistor, 0.64 ohm	EJ-154615 It. 18
75	1	1	Resistor, 0.80 ohm	EJ-154615 It. 19
76	1	1	Resistor, 1.00 ohm	EJ-154615 It. 20
77	1	1	Resistor, 1.60 ohms	EJ-154615 It. 21
78	1	1	Resistor, 2.00 ohms	EJ-154615 It. 22
79	1	1	Resistor, 2.40 ohms	EJ-154615 It. 23

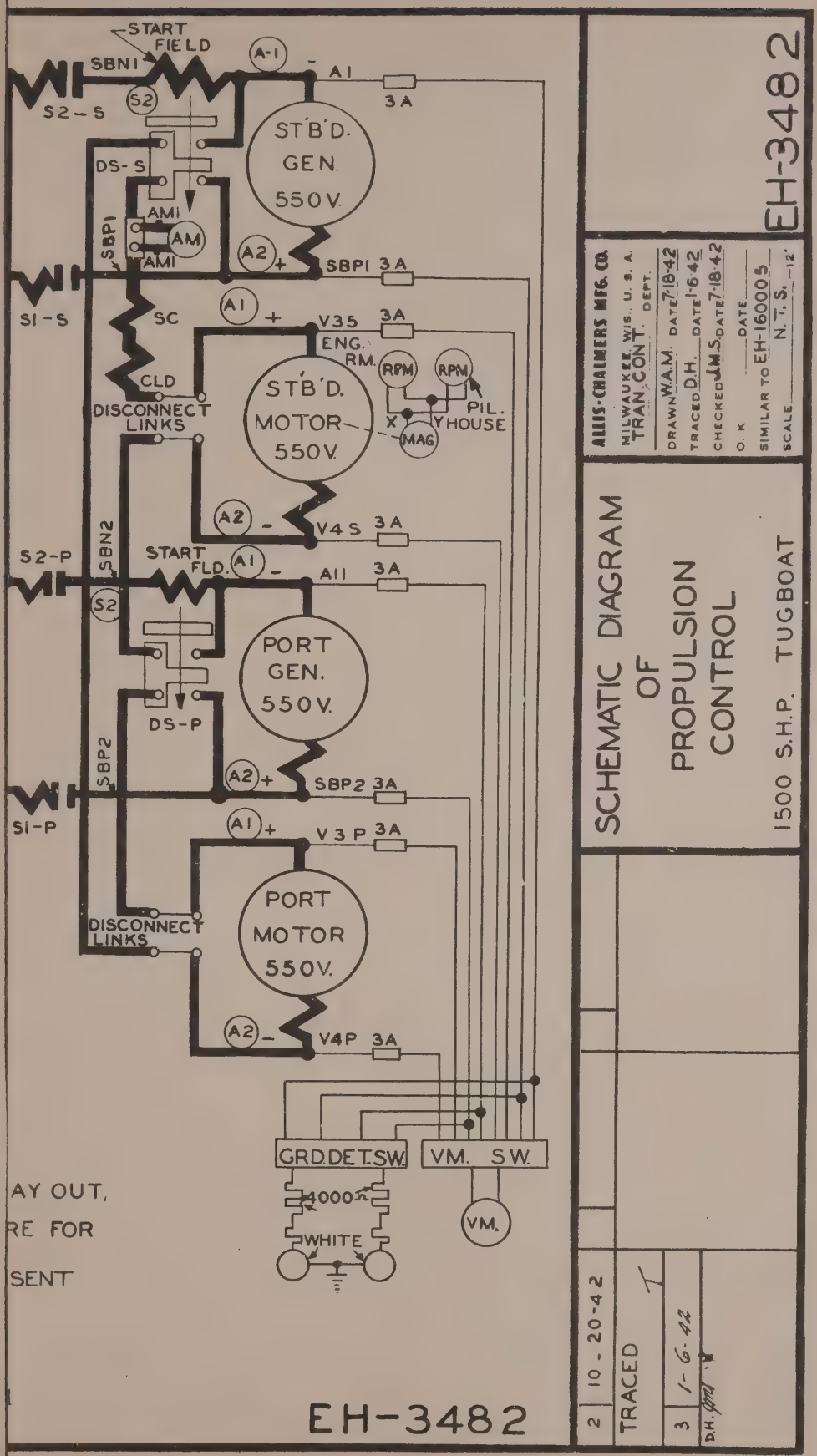
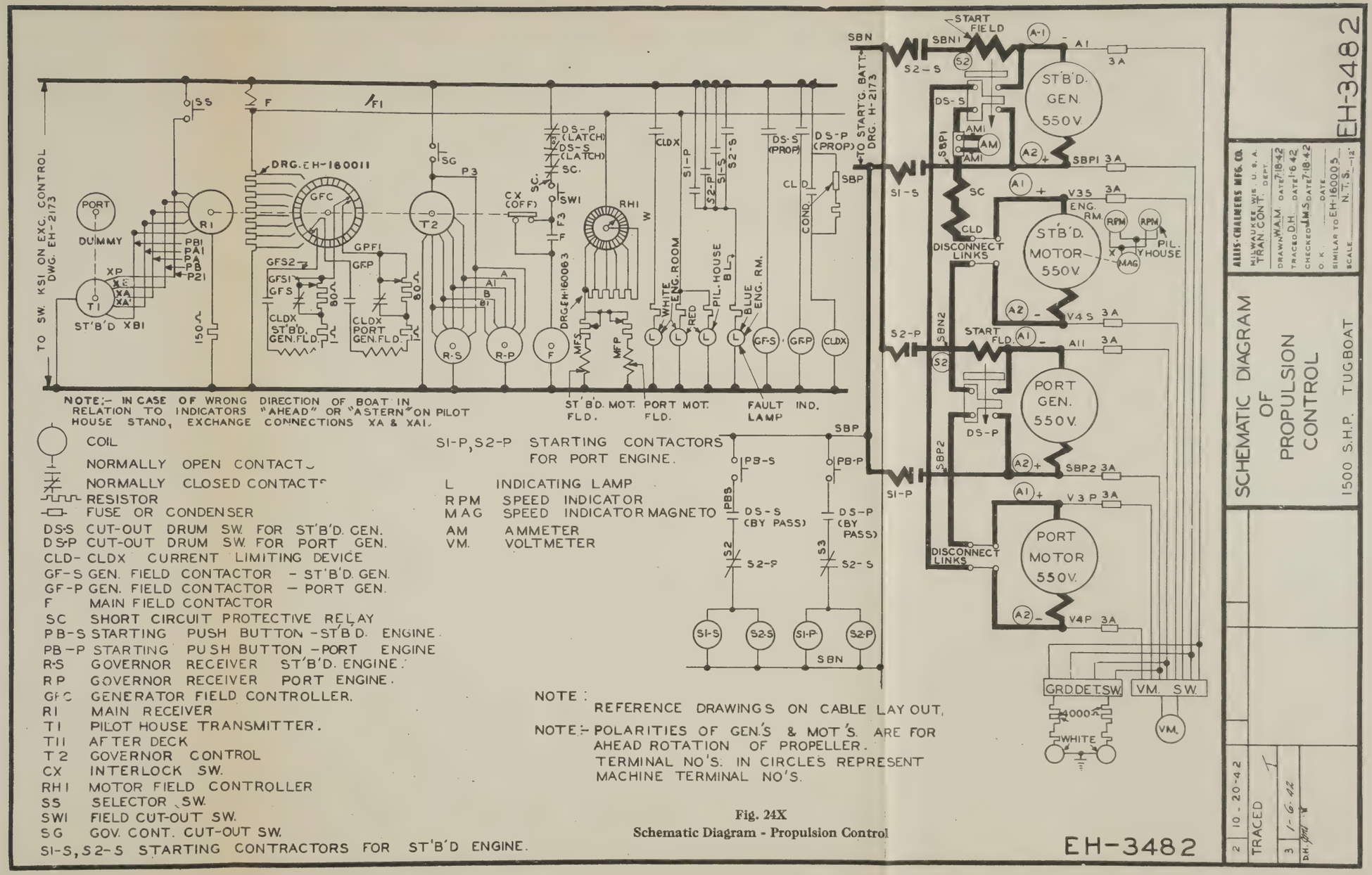

START FIELD
SBN1
S2-S
S2
A-1
A1
3A
ST'B'D. GEN. 550V.
DS-S
AM1
AM
SBP1
A2
SBP1 3A
S1-S
SC
A1
V35 3A
ENG. RM.
RPM
RPM
PIL. HOUSE
CLD
DISCONNECT LINKS
ST'B'D. MOTOR 550V.
X
Y
MAG
A2
V4S 3A
S2-P
SBN2
START FLD.
A1
A11 3A
S2
PORT GEN. 550V.
DS-P
SBP2
A2
SBP2 3A
S1-P
A1
V3P 3A
PORT MOTOR 550V.
DISCONNECT LINKS
A2
V4P 3A
GRD.DET.SW.
VM. SW.
4000Ω
WHITE
VM.
ALLIS-CHALMERS MFG. CO.
MILWAUKEE, WIS. U. S. A.
TRAN. CONT. DEPT.
DRAWN W.A.M. DATE 7-18-42
TRACED D.H. DATE 1-6-42
CHECKED J.M.S. DATE 7-18-42
O. K. DATE
SIMILAR TO EH-160005
SCALE N. T. S.
EH-3482
SCHEMATIC DIAGRAM OF PROPULSION CONTROL
1500 S.H.P. TUGBOAT
AY OUT,
RE FOR
SENT
2 10-20-42 TRACED
3 1-6-42 D.H.
EH-3482

Fig. 24X



NOTE:- IN CASE OF WRONG DIRECTION OF BOAT IN RELATION TO INDICATORS "AHEAD" OR "ASTERN" ON PILOT HOUSE STAND, EXCHANGE CONNECTIONS XA & XA1.

COIL
NORMALLY OPEN CONTACT
NORMALLY CLOSED CONTACT
RESISTOR
FUSE OR CONDENSER

DS-S CUT-OUT DRUM SW. FOR ST'B'D. GEN.
DS-P CUT-OUT DRUM SW. FOR PORT GEN.
CLD- CLDX CURRENT LIMITING DEVICE
GF-S GEN. FIELD CONTACTOR - ST'B'D. GEN.
GF-P GEN. FIELD CONTACTOR - PORT GEN.
F MAIN FIELD CONTACTOR
SC SHORT CIRCUIT PROTECTIVE RELAY
PB-S STARTING PUSH BUTTON - ST'B'D. ENGINE.
PB-P STARTING PUSH BUTTON - PORT ENGINE
R-S GOVERNOR RECEIVER ST'B'D. ENGINE.
R P GOVERNOR RECEIVER PORT ENGINE.
GFC GENERATOR FIELD CONTROLLER.
RI MAIN RECEIVER
TI PILOT HOUSE TRANSMITTER.
TII AFTER DECK
T2 GOVERNOR CONTROL
CX INTERLOCK SW.
RHI MOTOR FIELD CONTROLLER
SS SELECTOR SW.
SWI FIELD CUT-OUT SW.
SG GOV. CONT. CUT-OUT SW.
SI-S, S2-S STARTING CONTRACTORS FOR ST'B'D ENGINE.

SI-P, S2-P STARTING CONTACTORS FOR PORT ENGINE.

L INDICATING LAMP
RPM SPEED INDICATOR
MAG SPEED INDICATOR MAGNETO
AM AMMETER
VM. VOLTMETER

NOTE: REFERENCE DRAWINGS ON CABLE LAY OUT.

NOTE:- POLARITIES OF GEN.'S & MOT'S. ARE FOR AHEAD ROTATION OF PROPELLER. TERMINAL NO'S. IN CIRCLES REPRESENT MACHINE TERMINAL NO'S.

EH-3482

ALLIS-CHALMERS MFG. CO. MILWAUKEE WIS. U.S.A. TRANSM'N. DEPT.
DRAWN WAM DATE 7-18-42
TRACED D.H DATE 7-18-42
CHECKED LMS DATE 7-18-42
O. K. DATE
SIMILAR TO EH-160005
SCALE N.T.S. -12"

SCHEMATIC DIAGRAM OF PROPULSION CONTROL
1500 S.H.P. TUGBOAT

EH-3482

2 10-20-42 TRACED
3 1-6-43 DH

Fig. 24X
Schematic Diagram - Propulsion Control

Fig. 24X

E CURRENT RELAY
E ADJ. RHEO. FOR STBD. EXCITER
E ADJ. RHEO. FOR PORT EXCITER
RHEO. FOR AUX. GEN. #1
RHEO. FOR AUX. GEN. #2
CUT-OUT SW. FOR STBD. EXCITER
CUT-OUT SW. FOR PORT EXCITER
L SW. FOR SUPP. SHIPS SERVICE BUS
OL SW. FOR MAIN SHIPS SERVICE BUS
ER SW. FOR EXCITATION & CONTROL 4 P.D.T.
ER SW. FOR AUX. GENS.
ER SW. FOR SHIPS SERVICE BUSSES
R
TER

ITIES OF GEN'S. & MOT S. ARE FOR
" ROTATION OF PROPELLERS.
NALS NO'S. IN CIRCLES REPRESENT MACH.
NAL NO.'S.
E RESISTOR USED ON 2N-2494

EH-2173

3	8-12-42	TRACED
4	1-6-43	L.W. (10-6) ASTERIK AND ITS NOTE ADDED. EFF. 2N-3307
5	4-16-43	C.B. POSITION OF CONTACT MAKER ON PB1 R.F. VISED TO CONFORM WITH NEW TYPE SWITCH EFF 2N-3300
6	4-30-43	C.B.

ALLIS-CHALMERS MFG. CO.
MILWAUKEE, WIS., U. S. A.
TRAN. CONT. DEPT.
DRAWN C.B. DATE 1-28-42
TRACED L.W. DATE 1-6-43
CHECKED H.F.V. DATE 7-18-42
O. K. _____ DATE _____
SIMILAR TO EH-160006
SCALE N.T.S. —12"

EH-2173

SCHEMATIC DIAGRAM FOR AUX. CONTROL 1500 S.H.P. TUGBOAT

Fig. 25X

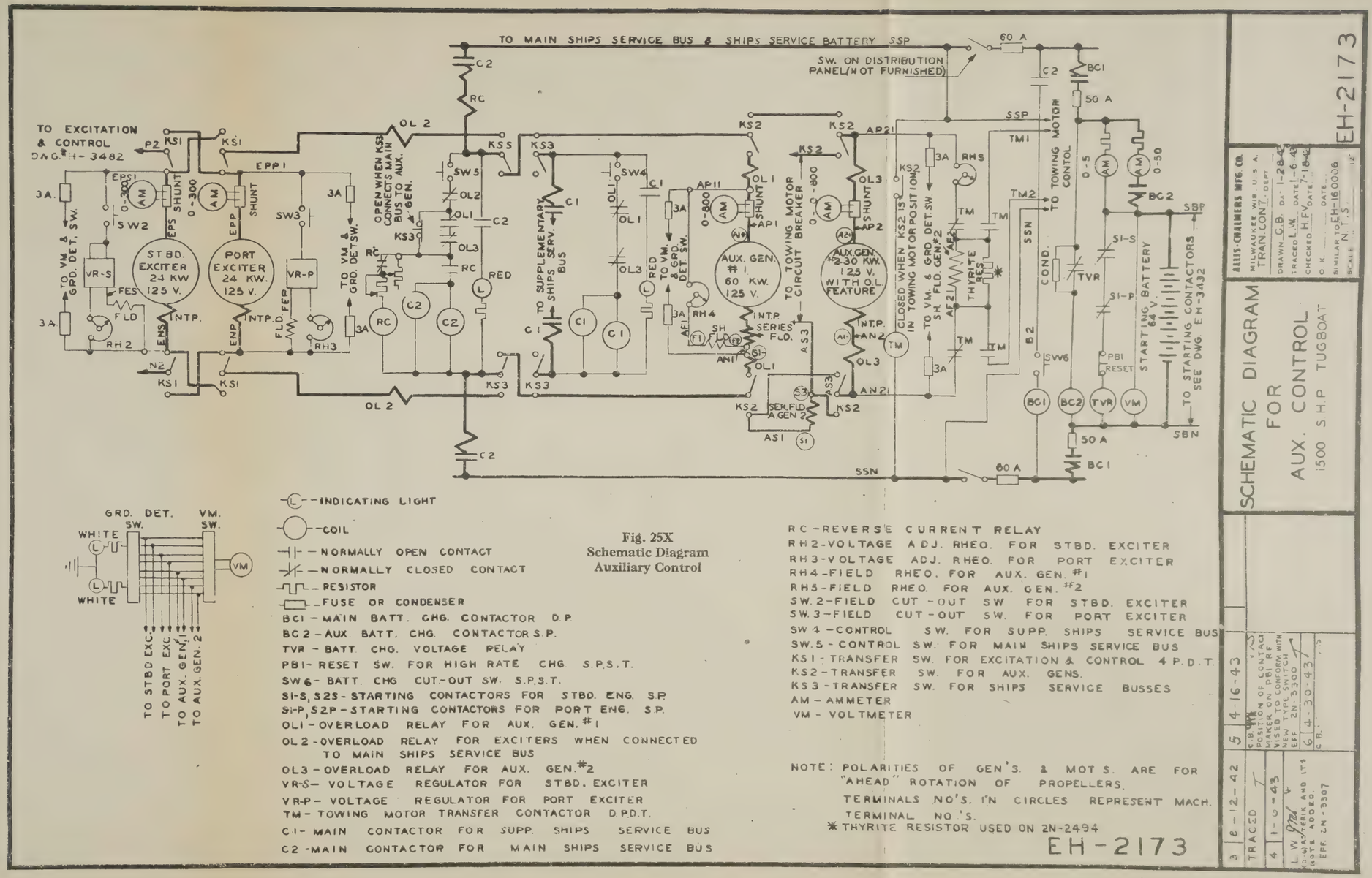

TO MAIN SHIPS SERVICE BUS & SHIPS SERVICE BATTERY SSP
SW. ON DISTRIBUTION PANEL (NOT FURNISHED)
60 A
TO EXCITATION & CONTROL DWG. EH-3482
OPEN WHEN KS3 CONNECTS MAIN BUS TO AUX. GEN.
TO SUPPLEMENTARY SHIPS SERV. BUS
TO TOWING MOTOR CIRCUIT BREAKER
CLOSED WHEN KS2 IS IN TOWING MOTOR POSITION
TO TOWING CONTOL
STBD. EXCITER 24 KW 125 V.
PORT EXCITER 24 KW. 125 V.
AUX. GEN. #1 60 KW. 125 V.
AUX. GEN. #2 30 KW. 125 V. WITH O.L. FEATURE
STARTING BATTERY 64 V
TO STARTING CONTACTORS SEE DWG. EH-3432
SSP
SSN
SBP
SBN
50 A
BC1
BC2
TVR
VM
GRD. DET. SW.
VM. SW.
WHITE
TO STBD EXC.
TO PORT EXC.
TO AUX. GEN. 1
TO AUX. GEN. 2

Fig. 25X
Schematic Diagram
Auxiliary Control

-(L)- INDICATING LIGHT
-( )- COIL
-| |- NORMALLY OPEN CONTACT
-|/|- NORMALLY CLOSED CONTACT
-/\/\- RESISTOR
-▭- FUSE OR CONDENSER

BC1 – MAIN BATT. CHG. CONTACTOR D.P.
BC2 – AUX. BATT. CHG. CONTACTOR S.P.
TVR – BATT. CHG. VOLTAGE RELAY
PB1 – RESET SW. FOR HIGH RATE CHG. S.P.S.T.
SW6 – BATT. CHG CUT-OUT SW. S.P.S.T.
S1-S, S2S – STARTING CONTACTORS FOR STBD. ENG. S.P.
S1-P, S2P – STARTING CONTACTORS FOR PORT ENG. S.P.
OL1 – OVERLOAD RELAY FOR AUX. GEN. #1
OL2 – OVERLOAD RELAY FOR EXCITERS WHEN CONNECTED TO MAIN SHIPS SERVICE BUS
OL3 – OVERLOAD RELAY FOR AUX. GEN. #2
VR-S – VOLTAGE REGULATOR FOR STBD. EXCITER
VR-P – VOLTAGE REGULATOR FOR PORT EXCITER
TM – TOWING MOTOR TRANSFER CONTACTOR D.P.D.T.
C1 – MAIN CONTACTOR FOR SUPP. SHIPS SERVICE BUS
C2 – MAIN CONTACTOR FOR MAIN SHIPS SERVICE BUS

RC – REVERSE CURRENT RELAY
RH2 – VOLTAGE ADJ. RHEO. FOR STBD. EXCITER
RH3 – VOLTAGE ADJ. RHEO. FOR PORT EXCITER
RH4 – FIELD RHEO. FOR AUX. GEN. #1
RH5 – FIELD RHEO. FOR AUX. GEN. #2
SW. 2 – FIELD CUT-OUT SW. FOR STBD. EXCITER
SW. 3 – FIELD CUT-OUT SW. FOR PORT EXCITER
SW. 4 – CONTROL SW. FOR SUPP. SHIPS SERVICE BUS
SW. 5 – CONTROL SW. FOR MAIN SHIPS SERVICE BUS
KS1 – TRANSFER SW. FOR EXCITATION & CONTROL 4 P.D.T.
KS2 – TRANSFER SW. FOR AUX. GENS.
KS3 – TRANSFER SW. FOR SHIPS SERVICE BUSSES
AM – AMMETER
VM – VOLTMETER

NOTE: POLARITIES OF GEN'S. & MOT'S. ARE FOR "AHEAD" ROTATION OF PROPELLERS.
TERMINALS NO'S. IN CIRCLES REPRESENT MACH. TERMINAL NO'S.
* THYRITE RESISTOR USED ON 2N-2494

EH-2173

ALLIS-CHALMERS MFG. CO. MILWAUKEE WIS. U.S.A. TRAN. CONT. DEPT.
DRAWN C.B. DATE 1-28-43
TRACED L.W. DATE 1-6-43
CHECKED H.F.V. DATE 1-18-43
O.K. ____ DATE ____
SIMILAR TO EH-16006
SCALE N.T.S.

SCHEMATIC DIAGRAM FOR AUX. CONTROL 1500 S.H.P. TUGBOAT

EH-2173

5	4-16-43	C.B.	CHANGE OF CONTACT FUNCTION OF PB1 AND SW6
3	2-12-42	TRACED	
4	1-6-43	L.W.	REVISED TO CONFORM WITH NEW TYPE SWITCH EFF. 2N-3300
6	4-30-43	C.B.	

(6-43) ASTERISK AND ITS NOTE ADDED. EFF. 2N-3307

Fig. 25X

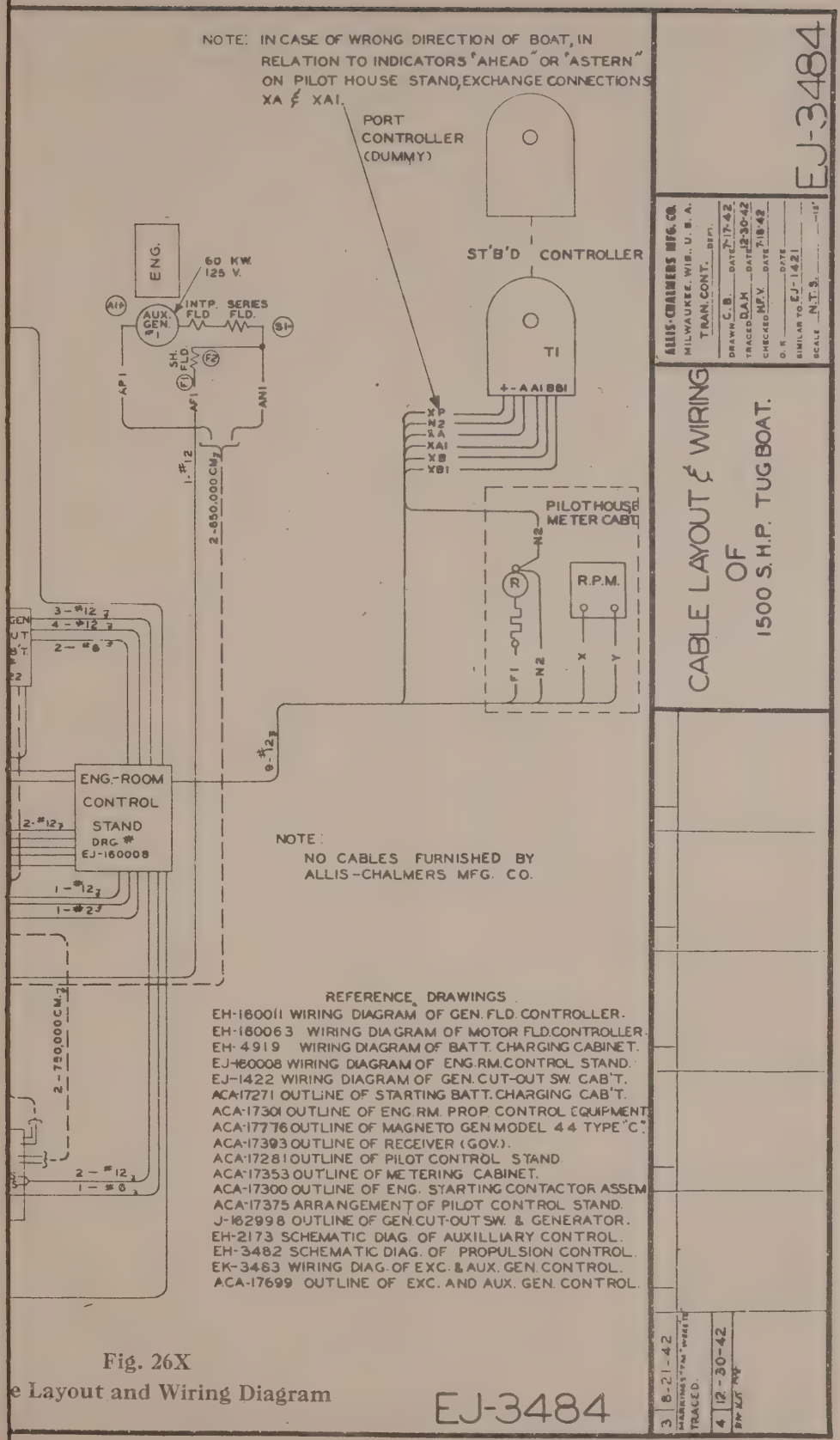

NOTE: IN CASE OF WRONG DIRECTION OF BOAT, IN RELATION TO INDICATORS "AHEAD" OR "ASTERN" ON PILOT HOUSE STAND, EXCHANGE CONNECTIONS XA & XA1.
PORT CONTROLLER (DUMMY)
ST'B'D CONTROLLER
TI
+ - A A1 B B1
ENG.
60 KW. 125 V.
AUX. GEN.
INTP. SERIES FLD.
SH. FLD.
PILOT HOUSE METER CAB'T.
R.P.M.
ENG.-ROOM CONTROL STAND DRG. # EJ-160008
NOTE: NO CABLES FURNISHED BY ALLIS-CHALMERS MFG. CO.
REFERENCE DRAWINGS
EH-160011 WIRING DIAGRAM OF GEN. FLD. CONTROLLER.
EH-160063 WIRING DIAGRAM OF MOTOR FLD. CONTROLLER.
EH-4919 WIRING DIAGRAM OF BATT. CHARGING CABINET.
EJ-160008 WIRING DIAGRAM OF ENG. RM. CONTROL STAND.
EJ-1422 WIRING DIAGRAM OF GEN. CUT-OUT SW. CAB'T.
ACA-17271 OUTLINE OF STARTING BATT. CHARGING CAB'T.
ACA-17301 OUTLINE OF ENG. RM. PROP. CONTROL EQUIPMENT.
ACA-17776 OUTLINE OF MAGNETO GEN. MODEL 44 TYPE "C".
ACA-17393 OUTLINE OF RECEIVER (GOV.).
ACA-17281 OUTLINE OF PILOT CONTROL STAND.
ACA-17353 OUTLINE OF METERING CABINET.
ACA-17300 OUTLINE OF ENG. STARTING CONTACTOR ASSEM.
ACA-17375 ARRANGEMENT OF PILOT CONTROL STAND.
J-162998 OUTLINE OF GEN. CUT-OUT SW. & GENERATOR.
EH-2173 SCHEMATIC DIAG. OF AUXILLIARY CONTROL.
EH-3482 SCHEMATIC DIAG. OF PROPULSION CONTROL.
EK-3483 WIRING DIAG. OF EXC. & AUX. GEN. CONTROL.
ACA-17699 OUTLINE OF EXC. AND AUX. GEN. CONTROL.
CABLE LAYOUT & WIRING OF 1500 S.H.P. TUG BOAT.
ALLIS-CHALMERS MFG. CO. MILWAUKEE, WIS., U.S.A. TRAN. CONT. DEPT.
DRAWN C.B. DATE 7-17-42
TRACED D.A.H. DATE 12-30-42
CHECKED M.F.V. DATE 7-18-42
O. K. DATE
SIMILAR TO EJ-1421
SCALE N.T.S.
EJ-3484
3 8-21-42
4 12-30-42
TRACED.
EJ-3484

Fig. 26X
e Layout and Wiring Diagram

Fig. 26X

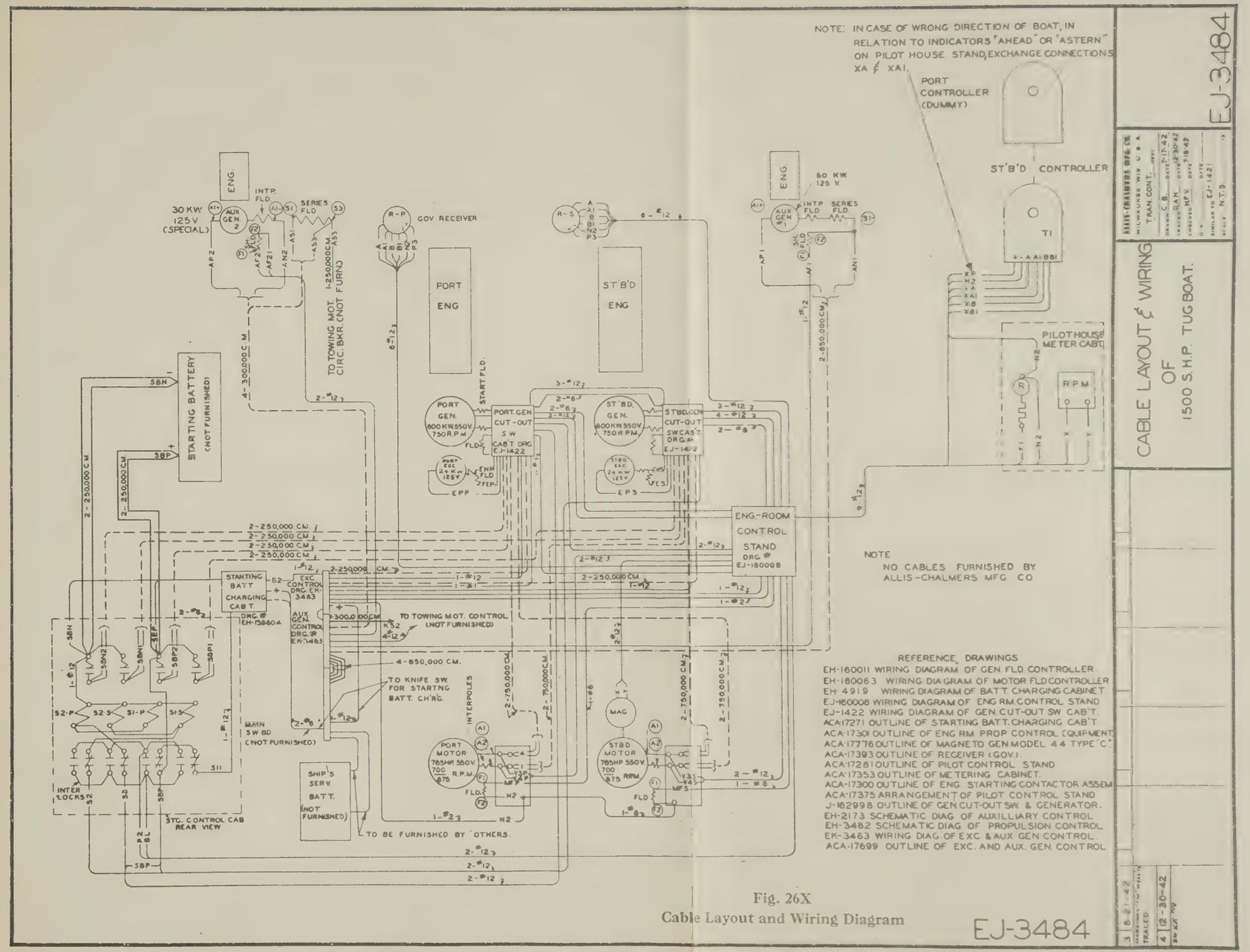

NOTE: IN CASE OF WRONG DIRECTION OF BOAT, IN RELATION TO INDICATORS "AHEAD" OR "ASTERN" ON PILOT HOUSE STAND, EXCHANGE CONNECTIONS XA & XA1.
PORT CONTROLLER (DUMMY)
ST'B'D CONTROLLER
TI
PILOT HOUSE METER CAB'T
RPM
ENG.-ROOM CONTROL STAND DRG. # EJ-160008
30 KW 125 V (SPECIAL)
AUX GEN 2
INTP. FLD.
SERIES FLD.
60 KW 125 V.
AUX GEN #1
SH. FLD.
GOV RECEIVER
PORT ENG
ST'B'D ENG
START FLD.
PORT GEN. 600 KW 550V 750 R.P.M.
PORT GEN. CUT-OUT SW CAB'T DRG EJ-1422
ST'BD. GEN. 600 KW 550V 750 R.P.M.
ST'BD GEN CUT-OUT SW CAB'T DRG. # EJ-1422
PORT EXC 2.6 KW 125 V
ST'BD EXC 2.6 KW 125 V
EPP
EPS
FLD
STARTING BATTERY (NOT FURNISHED)
STARTING BATT CHARGING CAB'T.
DRG. # EH-158604
EXC. CONTROL DRG. EK-3483
AUX. GEN. CONTROL DRG. # EK-3483
TO TOWING MOT. CIRC. BKR. (NOT FURN'D)
TO TOWING MOT. CONTROL (NOT FURNISHED)
TO KNIFE SW. FOR STARTNG BATT. CH'RG.
MAIN SW BD (NOT FURNISHED)
SHIP'S SERV. BATT. (NOT FURNISHED)
TO BE FURNISHED BY OTHERS.
STG. CONTROL CAB REAR VIEW
INTERLOCKS
INTERPOLES
MAG
PORT MOTOR 765HP 550V 700 R.P.M.
STBD MOTOR 765HP 550V 700 R.P.M.
MFS
NOTE
NO CABLES FURNISHED BY ALLIS-CHALMERS MFG CO
REFERENCE DRAWINGS
EH-160011 WIRING DIAGRAM OF GEN. FLD CONTROLLER
EH-160063 WIRING DIAGRAM OF MOTOR FLD CONTROLLER
EH-4919 WIRING DIAGRAM OF BATT. CHARGING CABINET
EJ-160008 WIRING DIAGRAM OF ENG RM. CONTROL STAND
EJ-1422 WIRING DIAGRAM OF GEN. CUT-OUT SW CAB'T.
ACA-17271 OUTLINE OF STARTING BATT. CHARGING CAB'T.
ACA-17301 OUTLINE OF ENG RM PROP CONTROL EQUIPMENT
ACA-17776 OUTLINE OF MAGNETO GEN MODEL 44 TYPE "C"
ACA-17393 OUTLINE OF RECEIVER (GOV.)
ACA-17281 OUTLINE OF PILOT CONTROL STAND
ACA-17353 OUTLINE OF METERING CABINET.
ACA-17300 OUTLINE OF ENG. STARTING CONTACTOR ASSEM.
ACA-17375 ARRANGEMENT OF PILOT CONTROL STAND
J-162998 OUTLINE OF GEN CUT-OUT SW. & GENERATOR.
EH-2173 SCHEMATIC DIAG OF AUXILLIARY CONTROL
EH-3482 SCHEMATIC DIAG OF PROPULSION CONTROL
EK-3483 WIRING DIAG. OF EXC. & AUX GEN CONTROL
ACA-17699 OUTLINE OF EXC. AND AUX. GEN. CONTROL
EJ-3484
ALLIS-CHALMERS MFG CO. MILWAUKEE WIS U.S.A.
TRAIN CONT.
DRAWN C.B. DATE 7-17-42
TRACED D.A.H. DATE 12-30-42
CHECKED M.F.V. DATE 7-18-42
DWG. NO. EJ-1421
SCALE NONE
CABLE LAYOUT & WIRING OF 1500 S.H.P. TUG BOAT.
3-18-42
4-12-30-42
TRACED

Fig. 26X
Cable Layout and Wiring Diagram

Fig. 26X

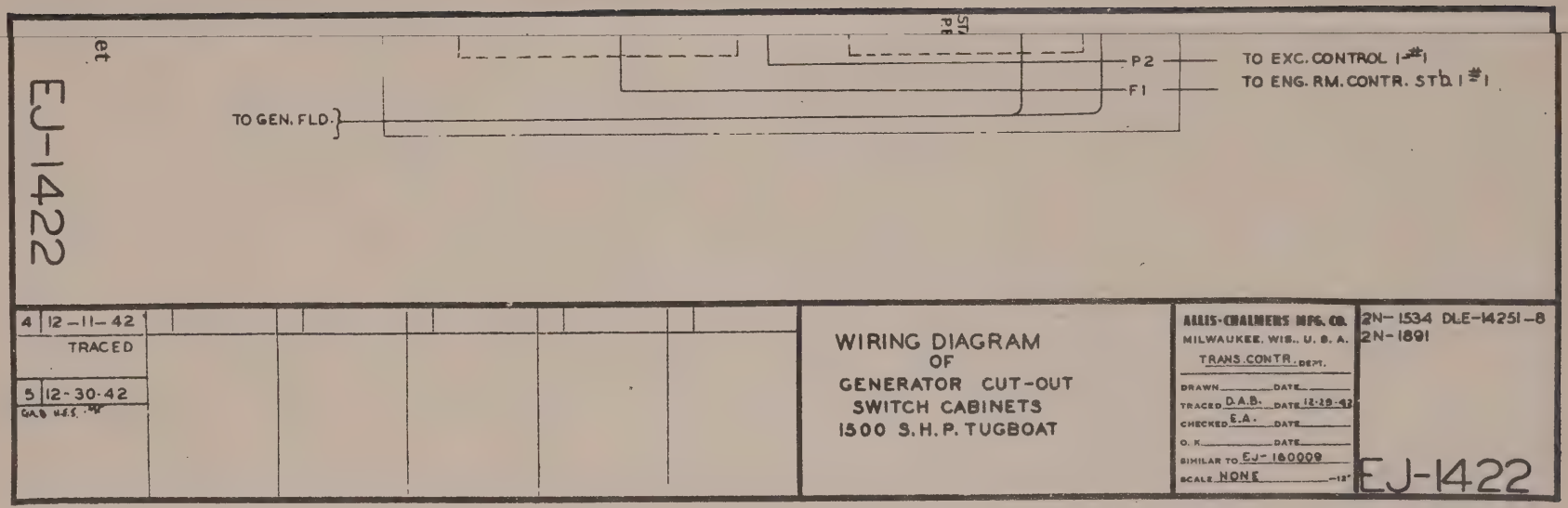

et
EJ-1422
TO GEN. FLD.
P2
F1
TO EXC. CONTROL 1-#1
TO ENG. RM. CONTR. STD. 1-#1
4 12-11-42
TRACED
5 12-30-42
WIRING DIAGRAM
OF
GENERATOR CUT-OUT
SWITCH CABINETS
1500 S.H.P. TUGBOAT
ALLIS-CHALMERS MFG. CO.
MILWAUKEE, WIS., U. S. A.
TRANS. CONTR. DEPT.
DRAWN DATE
TRACED D.A.B. DATE 12-29-42
CHECKED E.A. DATE
O. K. DATE
SIMILAR TO EJ-160009
SCALE NONE
2N-1534 DLE-14251-8
2N-1891
EJ-1422

Fig. 27X

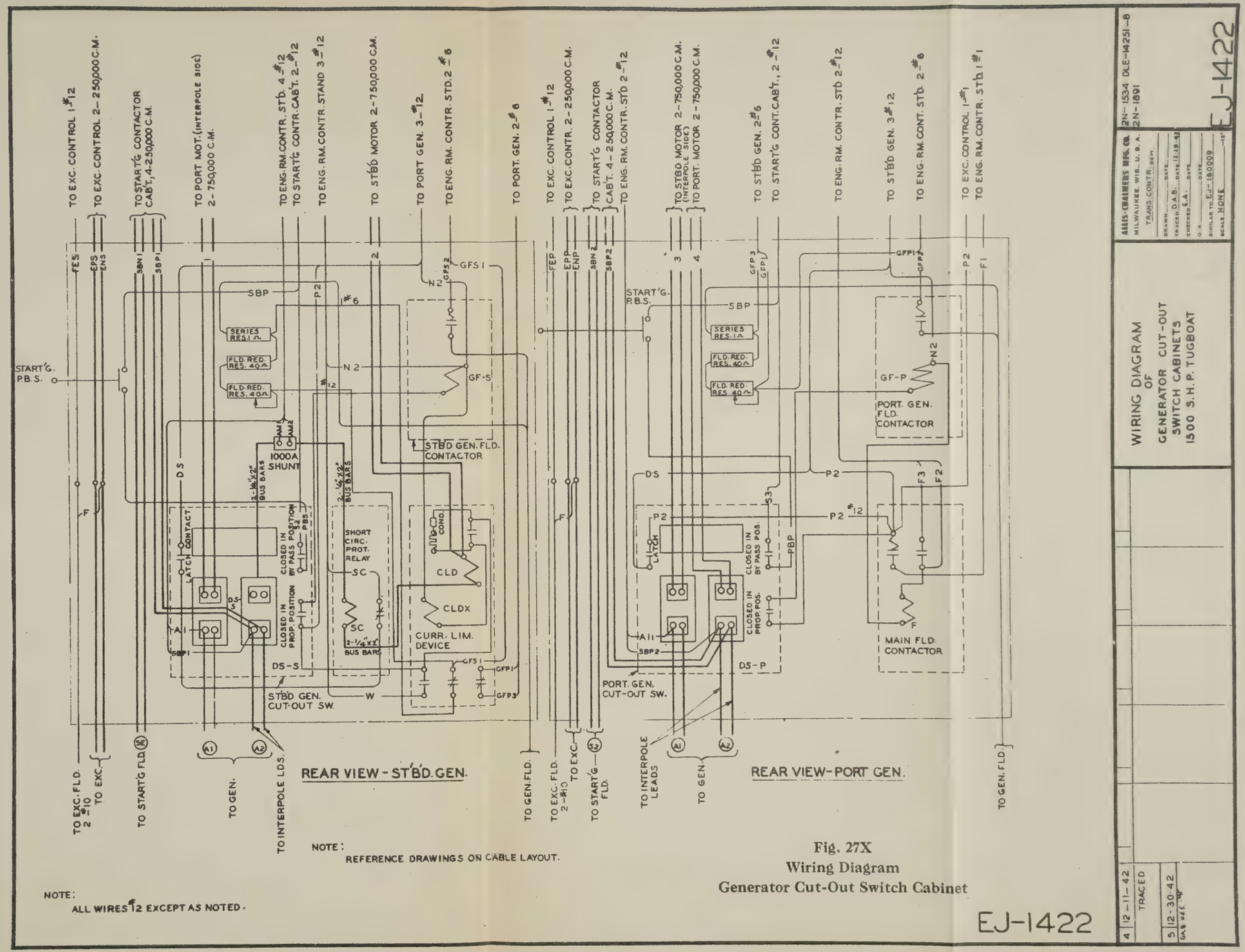

START'G. P.B.S.
TO EXC. CONTROL 1-#12
TO EXC. CONTROL 2-250,000 C.M.
TO START'G CONTACTOR CAB'T., 4-250,000 C.M.
TO PORT MOT. (INTERPOLE SIDE) 2-750,000 C.M.
TO ENG-RM. CONTR. STD. 4-#12
TO START'G CONTR. CAB'T. 2-#12
TO ENG. RM. CONTR. STAND 3-#12
TO STB'D MOTOR 2-750,000 C.M.
TO PORT GEN. 3-#12
TO ENG. RM. CONTR. STD. 2-#6
TO PORT. GEN. 2-#6
TO EXC. CONTROL 1-#12
TO EXC. CONTR. 2-250,000 C.M.
TO START'G CONTACTOR CAB'T. 4-250,000 C.M.
TO ENG. RM. CONTR. STD. 2-#12
TO STB'D MOTOR 2-750,000 C.M. (INTERPOLE SIDE)
TO PORT. MOTOR 2-750,000 C.M.
TO STB'D GEN. 2-#6
TO START'G CONT. CAB'T., 2-#12
TO ENG. RM. CONTR. STD. 2-#12
TO STB'D GEN. 3-#12
TO ENG-RM. CONT. STD. 2-#6
TO EXC. CONTROL 1-#1
TO ENG. RM. CONTR. STD. 1-#1
SERIES RES. 1Ω
FLD. RED. RES. 40Ω
1000A SHUNT
STBD GEN. FLD. CONTACTOR
SHORT CIRC. PROT. RELAY
CURR. LIM. DEVICE
CLD
CLDX
COND.
LATCH CONTACT
CLOSED IN PROP. POSITION
CLOSED IN BY PASS POS.
STBD GEN. CUT-OUT SW.
PORT. GEN. CUT-OUT SW.
PORT. GEN. FLD. CONTACTOR
MAIN FLD. CONTACTOR
REAR VIEW - STB'D. GEN.
REAR VIEW - PORT GEN.
TO EXC. FLD. 2-#10
TO EXC.
TO START'G FLD.
TO GEN.
TO INTERPOLE LDS.
TO GEN. FLD.
TO INTERPOLE LEADS
NOTE: REFERENCE DRAWINGS ON CABLE LAYOUT.
NOTE: ALL WIRES #12 EXCEPT AS NOTED.
ARIES-CHARMERS MFG. CO. MILWAUKEE, WIS. U.S.A. TRANS. CONTR. DEPT.
2N-1534 DLE-14251-B
2N-1801
WIRING DIAGRAM OF GENERATOR CUT-OUT SWITCH CABINETS 1500 S.H.P. TUGBOAT
DRAWN — DATE —
TRACED D.A.B. DATE 12-18-42
CHECKED E.A. — DATE —
O.K. — DATE —
SIMILAR TO E-J- 180009
SCALE NONE
EJ-1422
4 12-11-42 TRACED
5 12-30-42

Fig. 27X
Wiring Diagram
Generator Cut-Out Switch Cabinet

Fig. 27X

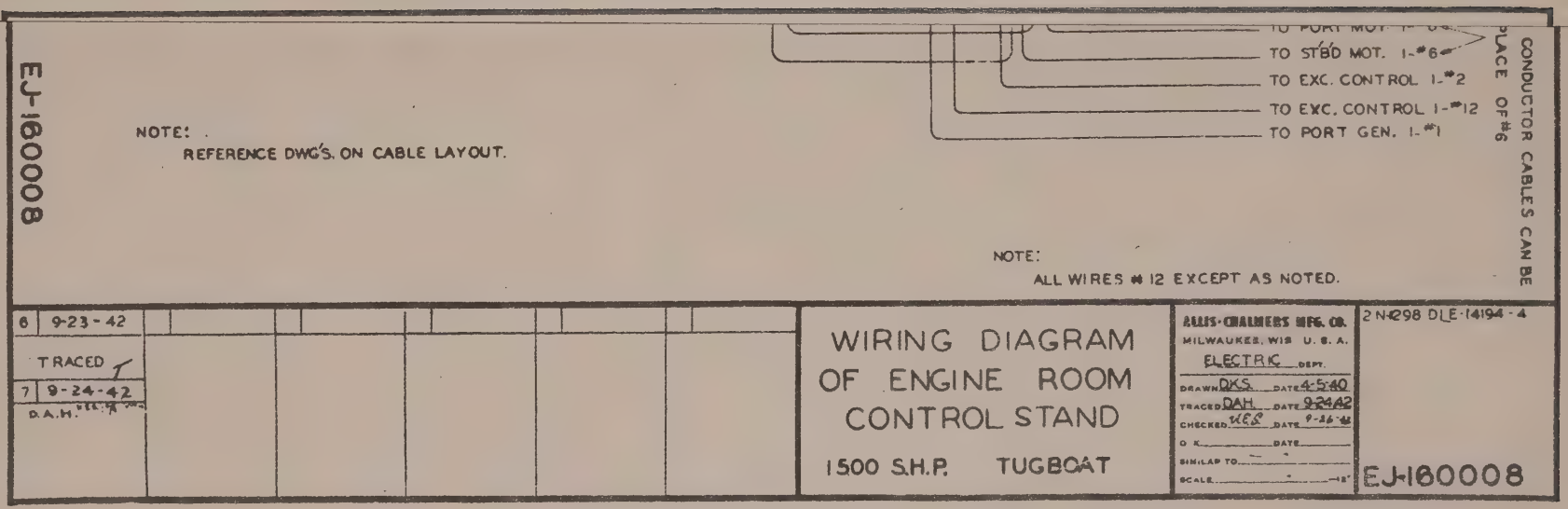

EJ-160008
NOTE:
REFERENCE DWG'S. ON CABLE LAYOUT.
TO PORT MOT. 1-#6
TO STBD MOT. 1-#6
TO EXC. CONTROL 1-#2
TO EXC. CONTROL 1-#12
TO PORT GEN. 1-#1
CONDUCTOR CABLES CAN BE PLACE OF #6
NOTE:
ALL WIRES #12 EXCEPT AS NOTED.
6 9-23-42
TRACED
7 9-24-42
D.A.H.
WIRING DIAGRAM OF ENGINE ROOM CONTROL STAND
1500 S.H.P. TUGBOAT
ALLIS-CHALMERS MFG. CO.
MILWAUKEE, WIS U. S. A.
ELECTRIC DEPT.
DRAWN DKS DATE 4-5-40
TRACED DAH DATE 9-24-42
CHECKED HES DATE 9-26-42
O. K. DATE
SIMILAR TO
SCALE
2 N-298 DLE-14194-4
EJ-160008

Fig. 28X

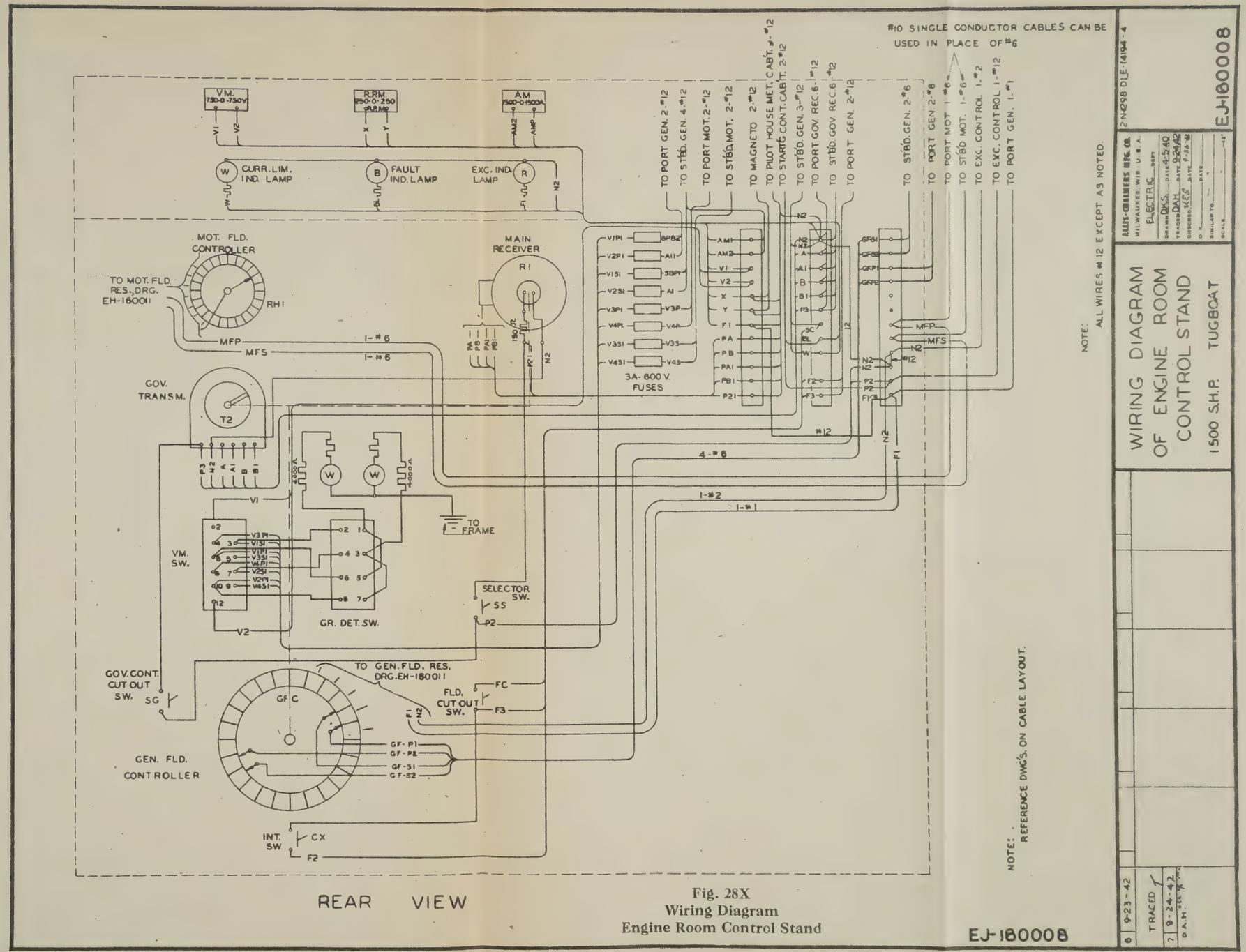


Fig. 28X
Wiring Diagram
Engine Room Control Stand

Fig. 28X

WIRING DIAGRAM
Ggovernor
TRANSMITTER
AS PER DWG. H-157412
2N-1295
DLF-14194-4
E
H-160064
ALLIS-CHALMERS MFG. CO.
MILWAUKEE, WIS., U.S.A.
DRAWN
TRACED
CHECKED
O.K.
SCALE NONE
BOTTOM VIEW
FLEXIBLE BRUSH CONNECTIONS
TO BRUSHES
ONS FROM ONE RING-HALF TO THE OTHER.
CTIONS MAY BE MADE BEFORE 1ST & 2ND LAYER
BLE.
ONS TO BE LAST OPERATION.
EH-160064

Fig. 29X

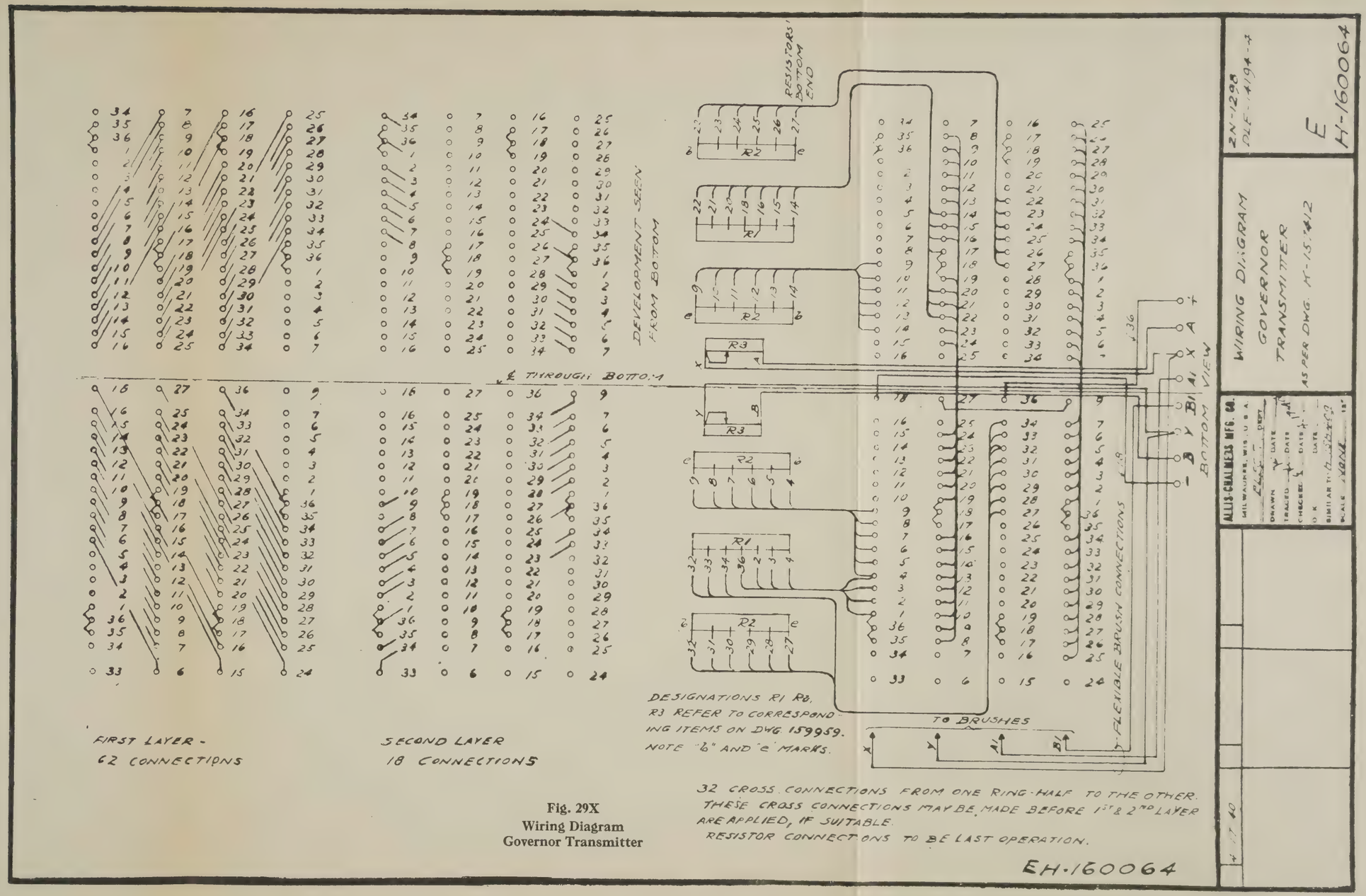

DEVELOPMENT SEEN FROM BOTTOM
RESISTORS BOTTOM END
THROUGH BOTTOM
FIRST LAYER - 62 CONNECTIONS
SECOND LAYER 18 CONNECTIONS
DESIGNATIONS R1 R2, R3 REFER TO CORRESPONDING ITEMS ON DWG 159959. NOTE "b" AND "e" MARKS.
TO BRUSHES
FLEXIBLE BRUSH CONNECTIONS
BOTTOM VIEW
32 CROSS CONNECTIONS FROM ONE RING-HALF TO THE OTHER. THESE CROSS CONNECTIONS MAY BE MADE BEFORE 1ST & 2ND LAYER ARE APPLIED, IF SUITABLE. RESISTOR CONNECTIONS TO BE LAST OPERATION.
EH-160064
WIRING DIAGRAM GOVERNOR TRANSMITTER
AS PER DWG. H-15.942
ALLIS-CHALMERS MFG. CO.
MILWAUKEE, WIS. U.S.A.
EH-160064

Fig. 29X
Wiring Diagram
Governor Transmitter

Fig. 29X

RES.
BOTTOM
END
R3
R3
R3
R3
B1
B
A1
A
(-)
(+)
9-27
WIRING DIAGRAM
PILOT HOUSE
TRANSMITTER
AS PER DWG. K-157400
ALLIS-CHALMERS MFG. CO.
MILWAUKEE, WIS. U.S.A.
ELECT. DEPT
DRAWN E.K.K. DATE 4-16-40
TRACED D.I.S. DATE 1-4-43
CHECKED DATE
O.K. DATE
SIMILAR TO H-157406
SCALE NONE
2N-1300
DLE-14303-4
EH-160065
OPERATION.
1, 2, 3
OTE "b" & "e"
EH-160065
1
1-6-43

Fig. 30X

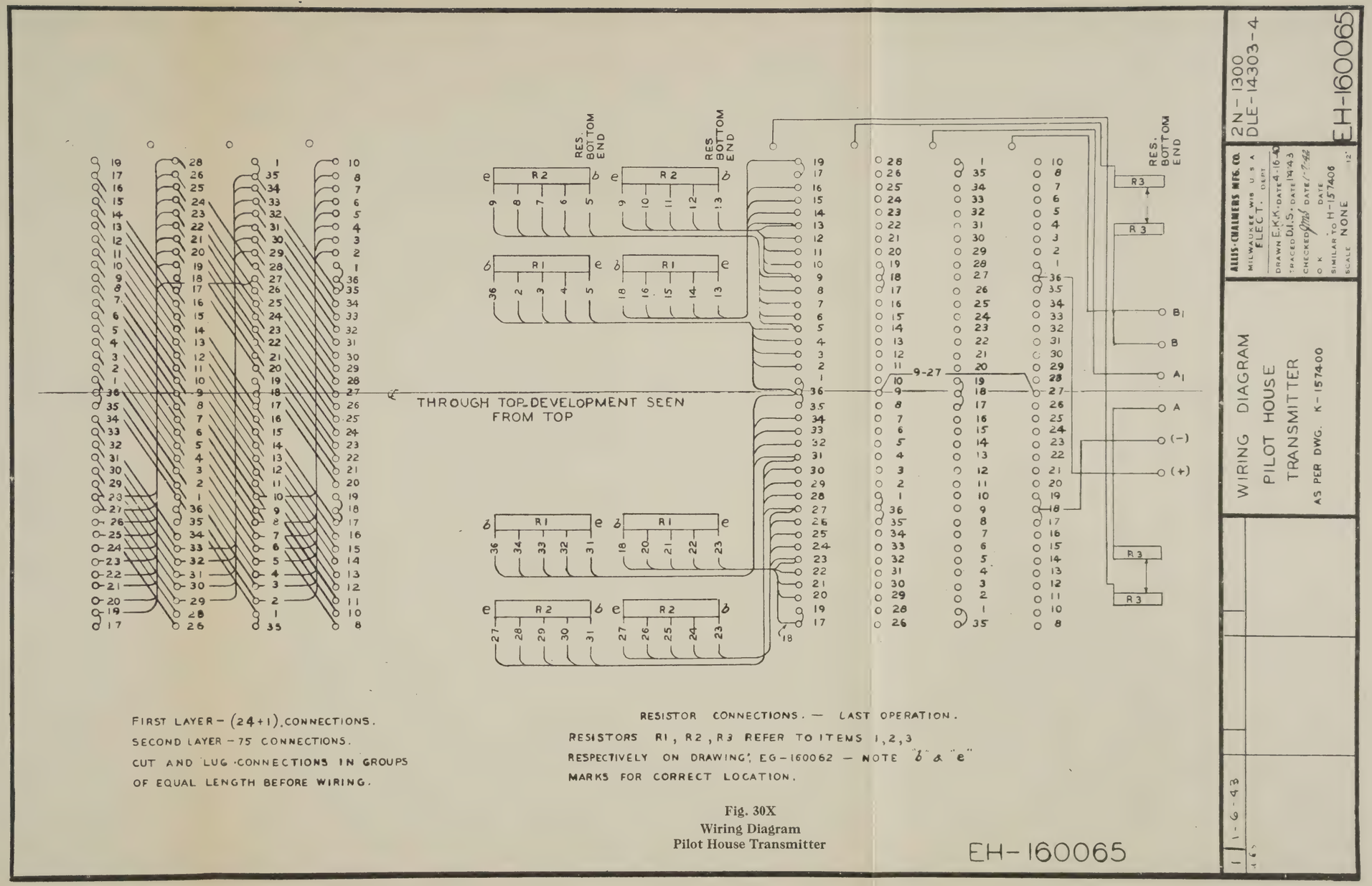


Fig. 30X
Wiring Diagram
Pilot House Transmitter

Fig. 30X

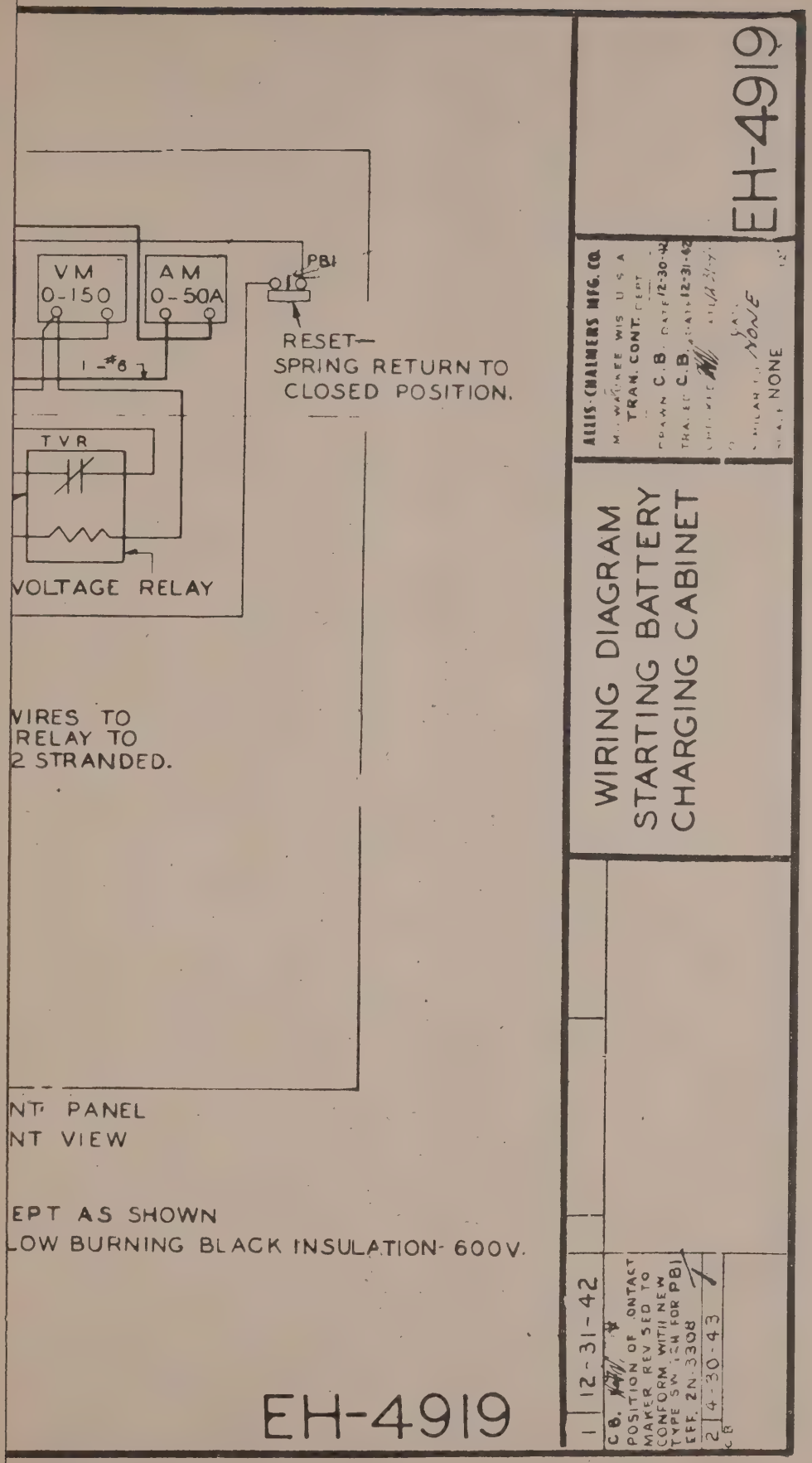

VM
0-150
AM
0-50A
PB1
RESET—
SPRING RETURN TO
CLOSED POSITION.
1 - #8
TVR
VOLTAGE RELAY
VIRES TO
RELAY TO
2 STRANDED.
NT PANEL
NT VIEW
EPT AS SHOWN
LOW BURNING BLACK INSULATION- 600V.
EH-4919
ALLIS-CHALMERS MFG. CO.
TRAN. CONT. DEPT
DRAWN C.B. DATE 12-30-42
TRACED C.B. DATE 12-31-42
NONE
WIRING DIAGRAM
STARTING BATTERY
CHARGING CABINET
EH-4919
1 12-31-42
C.B.
POSITION OF CONTACT MAKER REVISED TO CONFORM WITH NEW TYPE SW. ITEM FOR PB1
EFF. ZN-3308
2 4-30-43
C.B.

Fig. 31X

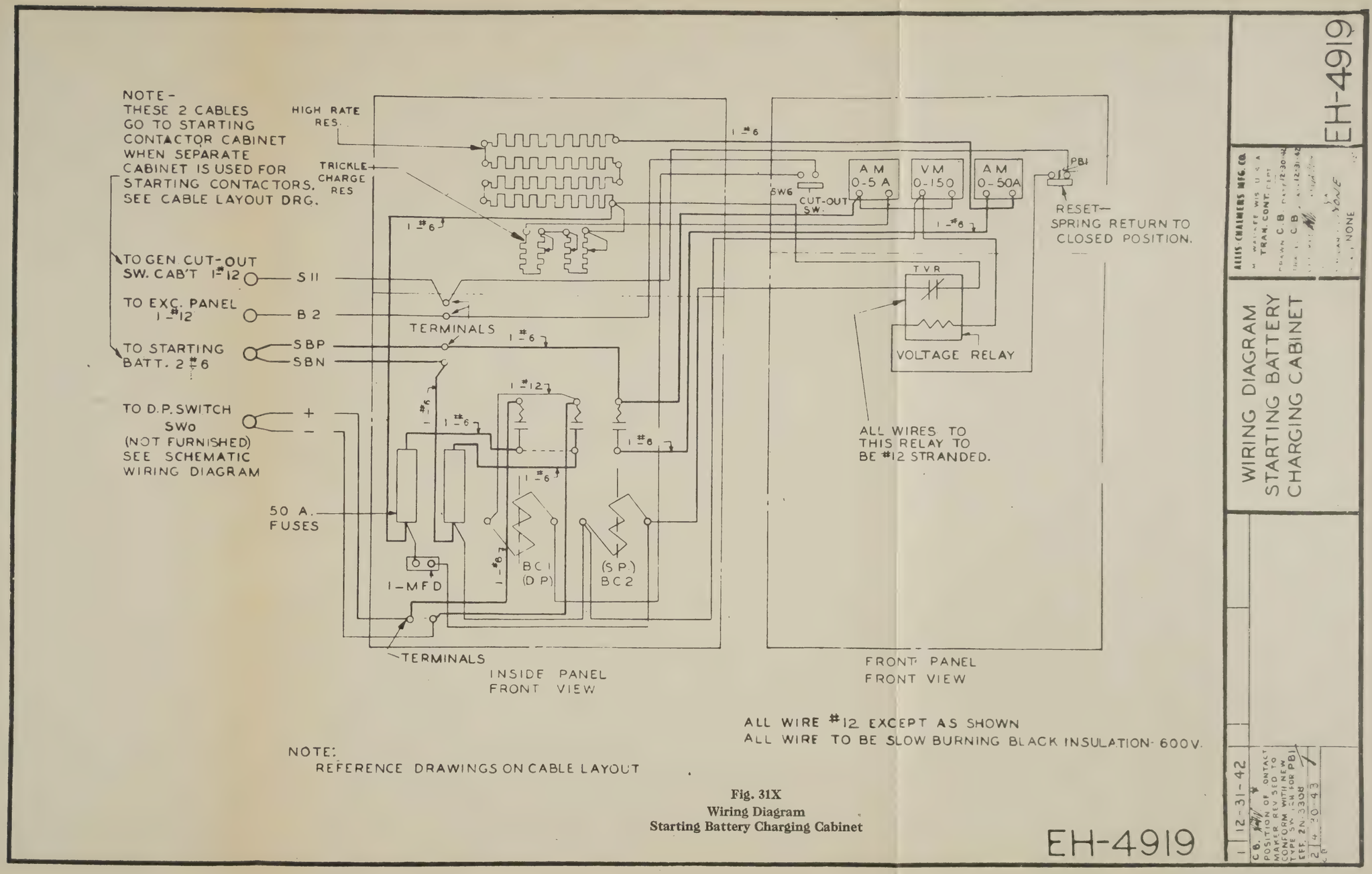


Fig. 31X
Wiring Diagram
Starting Battery Charging Cabinet

Fig. 31X

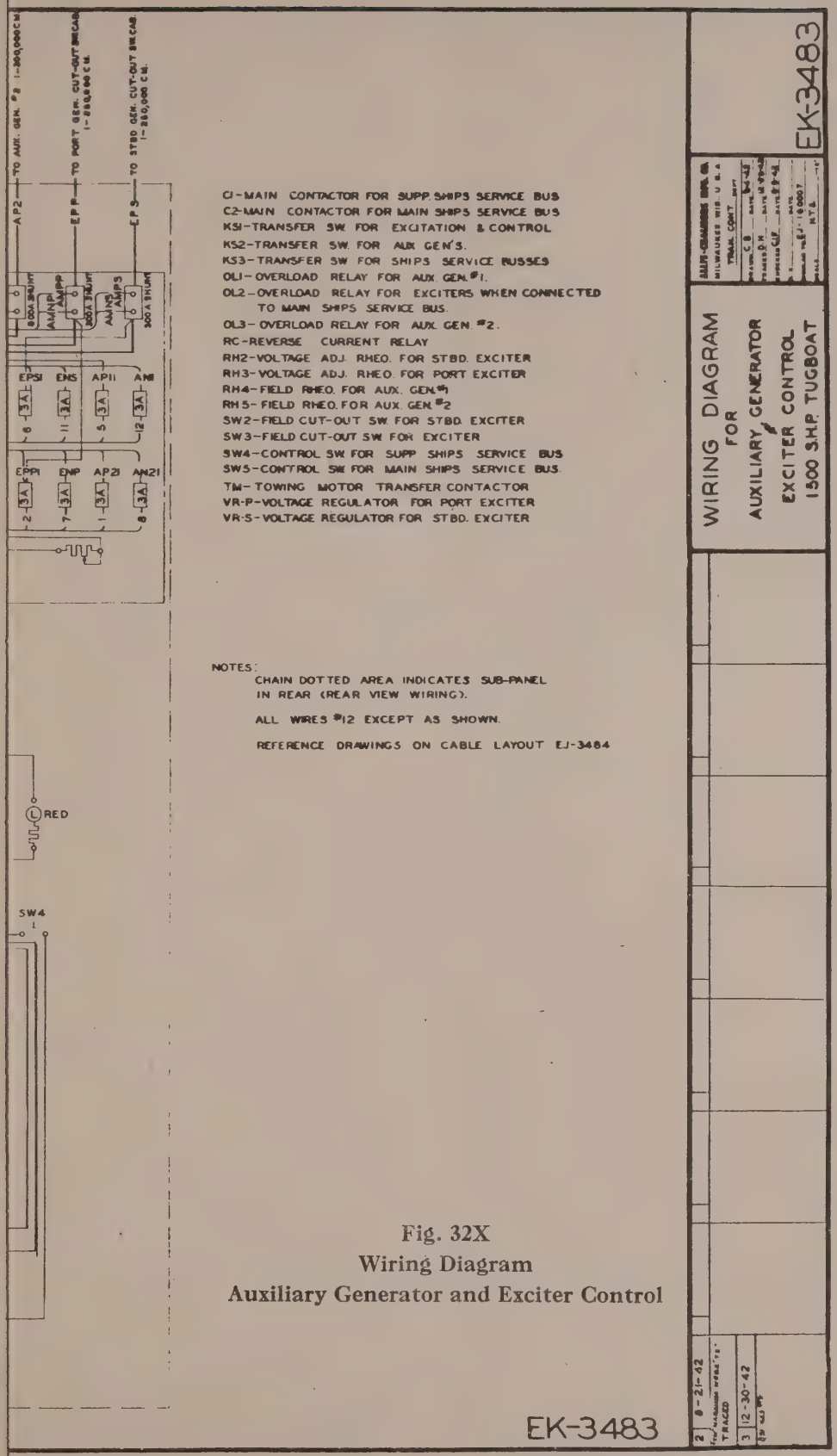

C1-MAIN CONTACTOR FOR SUPP. SHIPS SERVICE BUS
C2-MAIN CONTACTOR FOR MAIN SHIPS SERVICE BUS
KS1-TRANSFER SW. FOR EXCITATION & CONTROL
KS2-TRANSFER SW. FOR AUX. GEN'S.
KS3-TRANSFER SW. FOR SHIPS SERVICE BUSSES
OL1-OVERLOAD RELAY FOR AUX. GEN. #1.
OL2-OVERLOAD RELAY FOR EXCITERS WHEN CONNECTED TO MAIN SHIPS SERVICE BUS.
OL3-OVERLOAD RELAY FOR AUX. GEN. #2.
RC-REVERSE CURRENT RELAY
RH2-VOLTAGE ADJ. RHEO. FOR STBD. EXCITER
RH3-VOLTAGE ADJ. RHEO. FOR PORT EXCITER
RH4-FIELD RHEO. FOR AUX. GEN. #1
RH5-FIELD RHEO. FOR AUX. GEN. #2
SW2-FIELD CUT-OUT SW. FOR STBD. EXCITER
SW3-FIELD CUT-OUT SW. FOR EXCITER
SW4-CONTROL SW. FOR SUPP. SHIPS SERVICE BUS
SW5-CONTROL SW. FOR MAIN SHIPS SERVICE BUS.
TM-TOWING MOTOR TRANSFER CONTACTOR
VR-P-VOLTAGE REGULATOR FOR PORT EXCITER
VR-S-VOLTAGE REGULATOR FOR STBD. EXCITER
NOTES:
CHAIN DOTTED AREA INDICATES SUB-PANEL IN REAR (REAR VIEW WIRING).
ALL WIRES #12 EXCEPT AS SHOWN.
REFERENCE DRAWINGS ON CABLE LAYOUT EJ-3484
WIRING DIAGRAM FOR AUXILIARY GENERATOR EXCITER CONTROL 1500 S.H.P. TUGBOAT
EK-3483
EK-3483

Fig. 32X
Wiring Diagram
Auxiliary Generator and Exciter Control

Fig. 32X

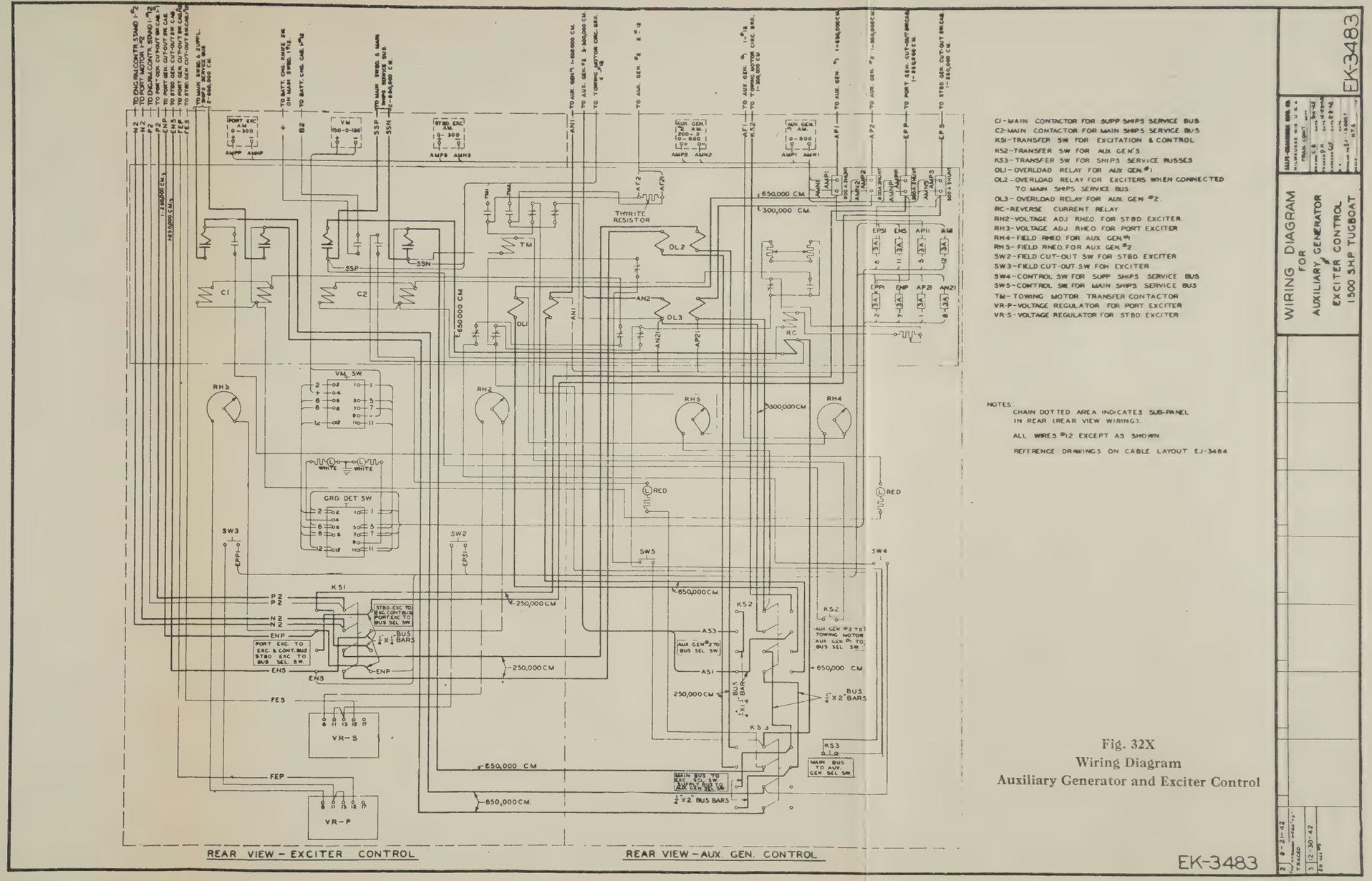
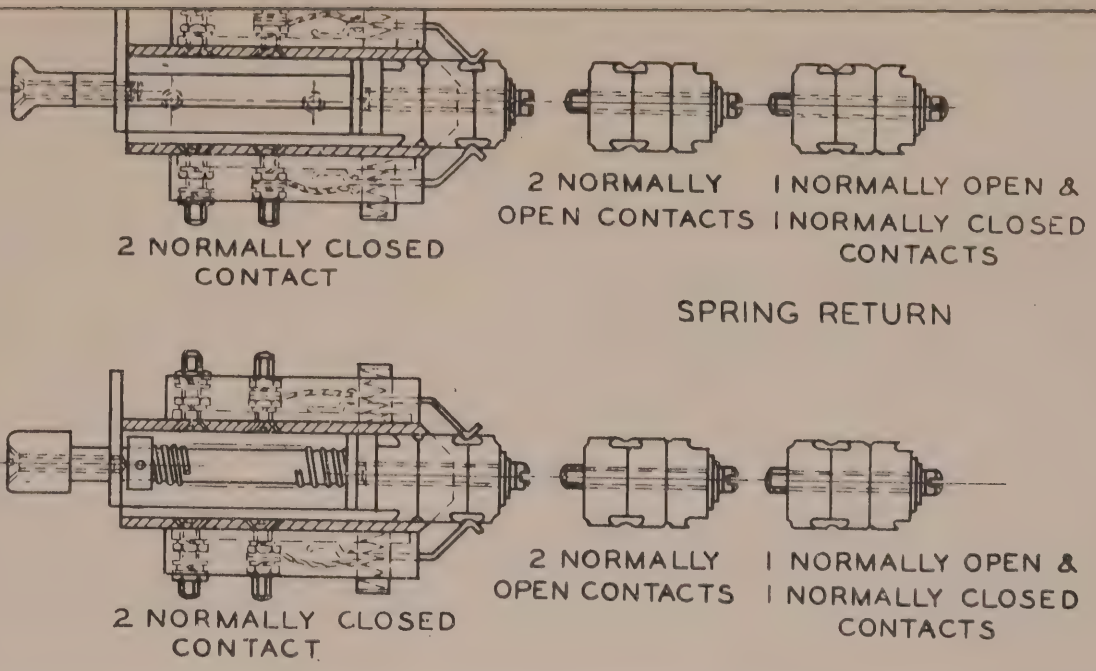

C1 - MAIN CONTACTOR FOR SUPP SHIPS SERVICE BUS
C2 - MAIN CONTACTOR FOR MAIN SHIPS SERVICE BUS
KS1 - TRANSFER SW FOR EXCITATION & CONTROL
KS2 - TRANSFER SW FOR AUX GEN'S.
KS3 - TRANSFER SW FOR SHIPS SERVICE BUSSES
OL1 - OVERLOAD RELAY FOR AUX GEN. #1
OL2 - OVERLOAD RELAY FOR EXCITERS WHEN CONNECTED TO MAIN SHIPS SERVICE BUS
OL3 - OVERLOAD RELAY FOR AUX GEN #2.
RC - REVERSE CURRENT RELAY
RH2 - VOLTAGE ADJ. RHEO. FOR STBD EXCITER
RH3 - VOLTAGE ADJ. RHEO FOR PORT EXCITER
RH4 - FIELD RHEO. FOR AUX GEN. #1
RH5 - FIELD RHEO. FOR AUX GEN. #2
SW2 - FIELD CUT-OUT SW FOR STBD EXCITER
SW3 - FIELD CUT-OUT SW FOR EXCITER
SW4 - CONTROL SW FOR SUPP SHIPS SERVICE BUS
SW5 - CONTROL SW FOR MAIN SHIPS SERVICE BUS
TM - TOWING MOTOR TRANSFER CONTACTOR
VR-P - VOLTAGE REGULATOR FOR PORT EXCITER
VR-S - VOLTAGE REGULATOR FOR STBD. EXCITER
NOTES:
CHAIN DOTTED AREA INDICATES SUB-PANEL IN REAR (REAR VIEW WIRING).
ALL WIRES #12 EXCEPT AS SHOWN
REFERENCE DRAWINGS ON CABLE LAYOUT EJ-3484
REAR VIEW - EXCITER CONTROL
REAR VIEW - AUX. GEN. CONTROL
EK-3483
WIRING DIAGRAM FOR AUXILIARY GENERATOR EXCITER CONTROL 1500 SHP TUGBOAT
EK-3483

Fig. 32X
Wiring Diagram
Auxiliary Generator and Exciter Control

Fig. 32X


2 NORMALLY CLOSED CONTACT
2 NORMALLY OPEN CONTACTS
1 NORMALLY OPEN & 1 NORMALLY CLOSED CONTACTS
SPRING RETURN
2 NORMALLY CLOSED CONTACT
2 NORMALLY OPEN CONTACTS
1 NORMALLY OPEN & 1 NORMALLY CLOSED CONTACTS

1 | 1-6-43			
1B GMH.			

ILLUSTRATION OF PUSH BUTTON SWITCH (10 AMPERES)

ALLIS-CHALMERS MFG. CO.
MILWAUKEE, WIS., U. S. A.
ELEC CONT DEPT.

DRAWN U.S. DATE 12/31/42
TRACED J.B. DATE 1/9/43
CHECKED GMH DATE 1-6-43
O.K. ____ DATE ____
SIMILAR TO ____
SCALE N.T.S. -12-

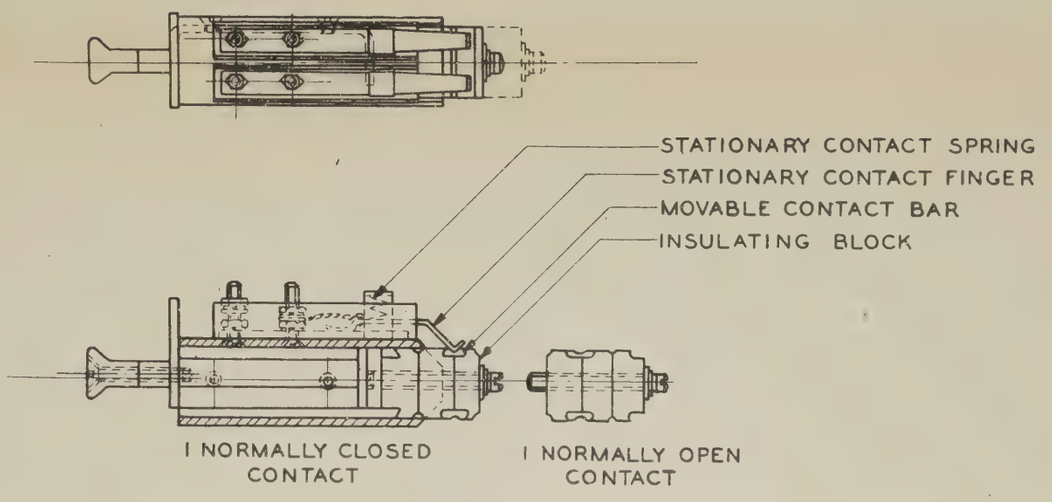
ACA-17789

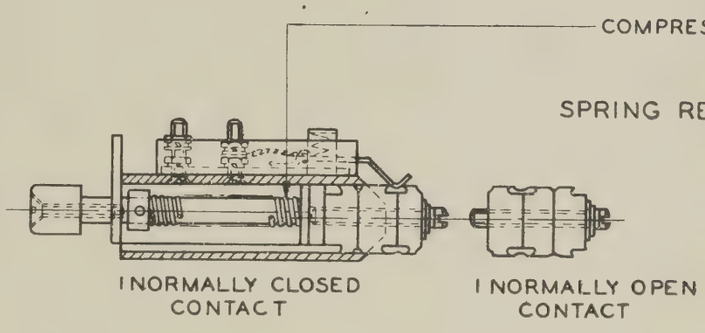
ACA-17789

Fig. 33X

SINGLE POLE

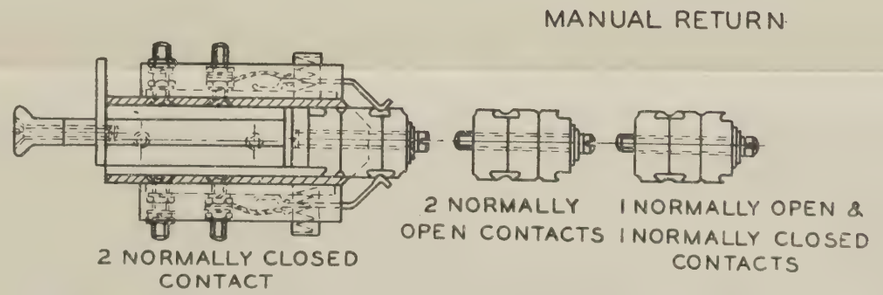
MANUAL RETURN





DOUBLE POLE

MANUAL RETURN



SPRING RETURN

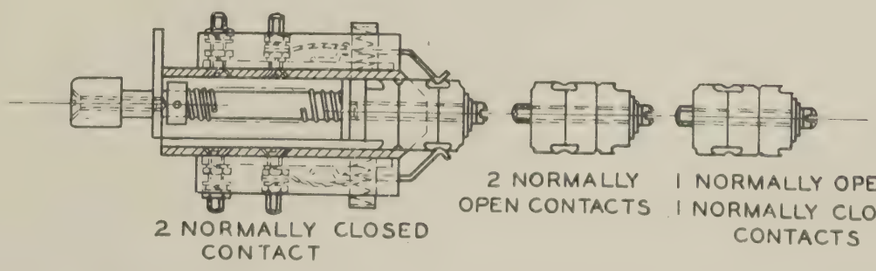


Fig. 33X
Push Button Switch (10 Amperes)

ACA-17789

1 | 1-6-43 1B Mod.		ILLUSTRATION OF PUSH BUTTON SWITCH (10 AMPERES)	ALLIS-CHALMERS MFG. CO. MILWAUKEE, WIS., U. S. A. ELEC CONT DEPT. DRAWN V. S. DATE 12/31/42 TRACED J. B. DATE 1/4/43 CHECKED DATE 1-6-43 O K DATE SIMILAR TO SCALE NTS. -12-	ACA-17789

Fig. 33X

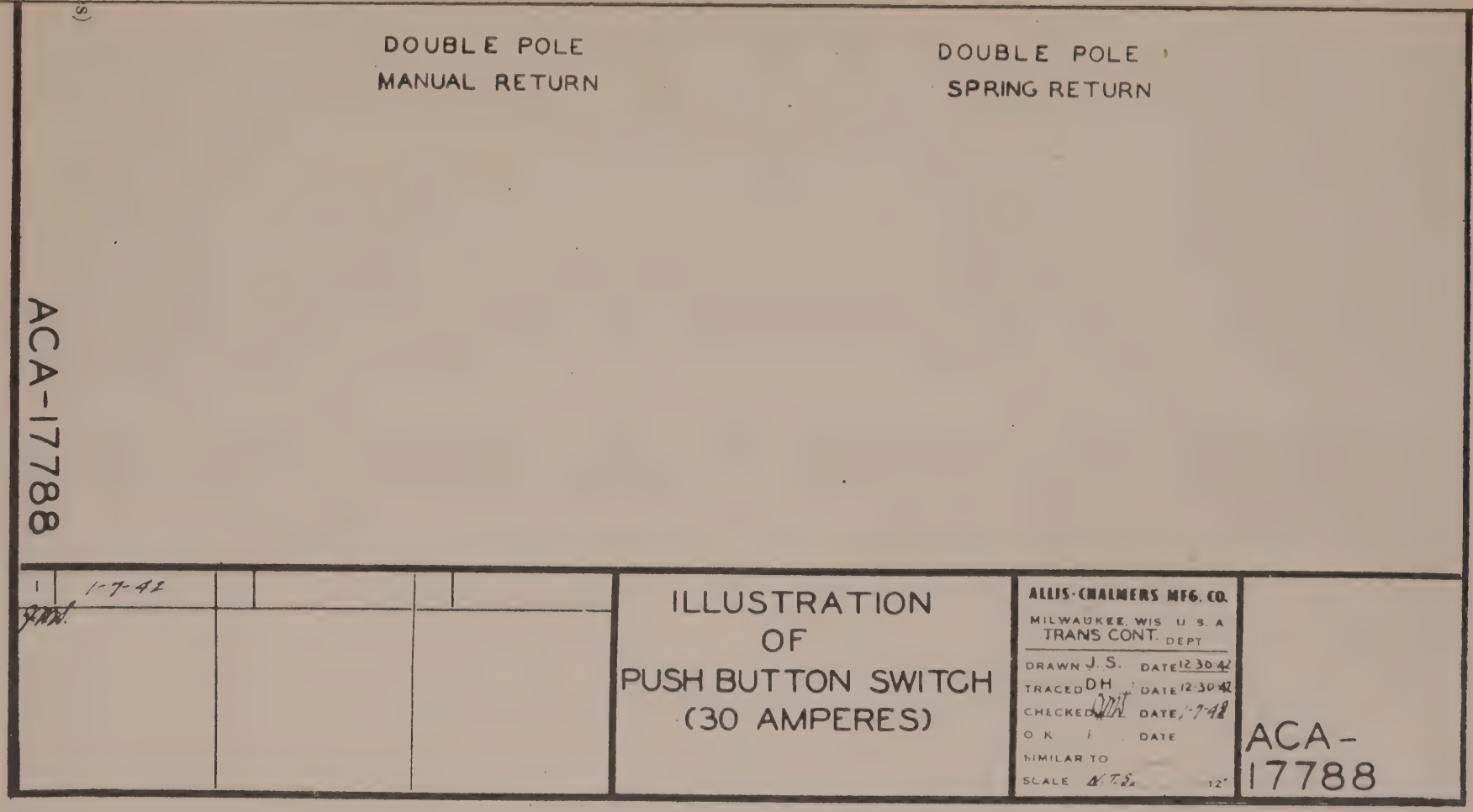

DOUBLE POLE
MANUAL RETURN
DOUBLE POLE
SPRING RETURN
ACA-17788
1-7-42
ILLUSTRATION
OF
PUSH BUTTON SWITCH
(30 AMPERES)
ALLIS-CHALMERS MFG. CO.
MILWAUKEE, WIS U. S. A.
TRANS CONT. DEPT
DRAWN J. S. DATE 12-30-42
TRACED DH DATE 12-30-42
CHECKED DATE 1-7-43
O K DATE
SIMILAR TO
SCALE N.T.S. 12"
ACA-
17788

Fig. 34X

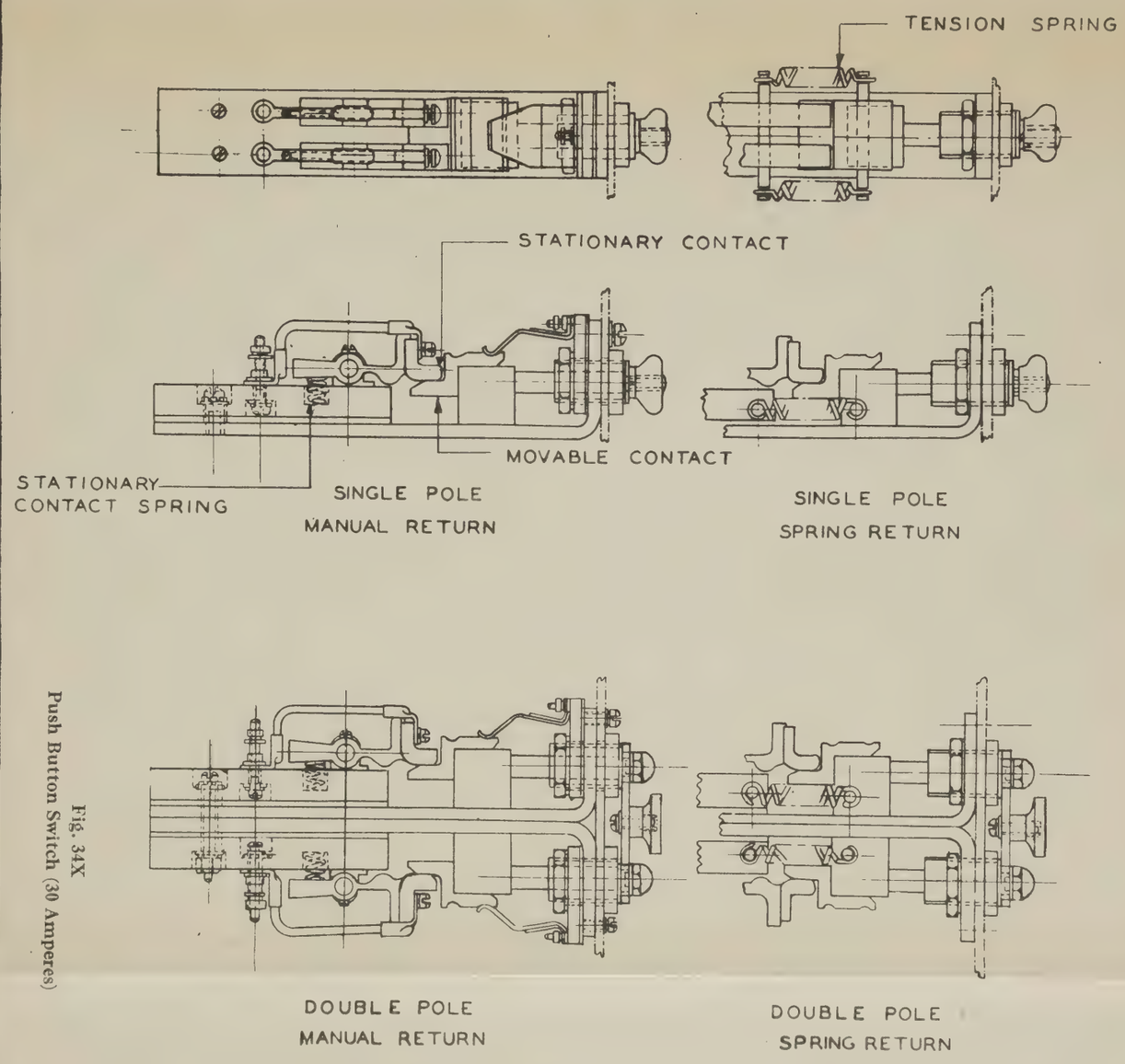
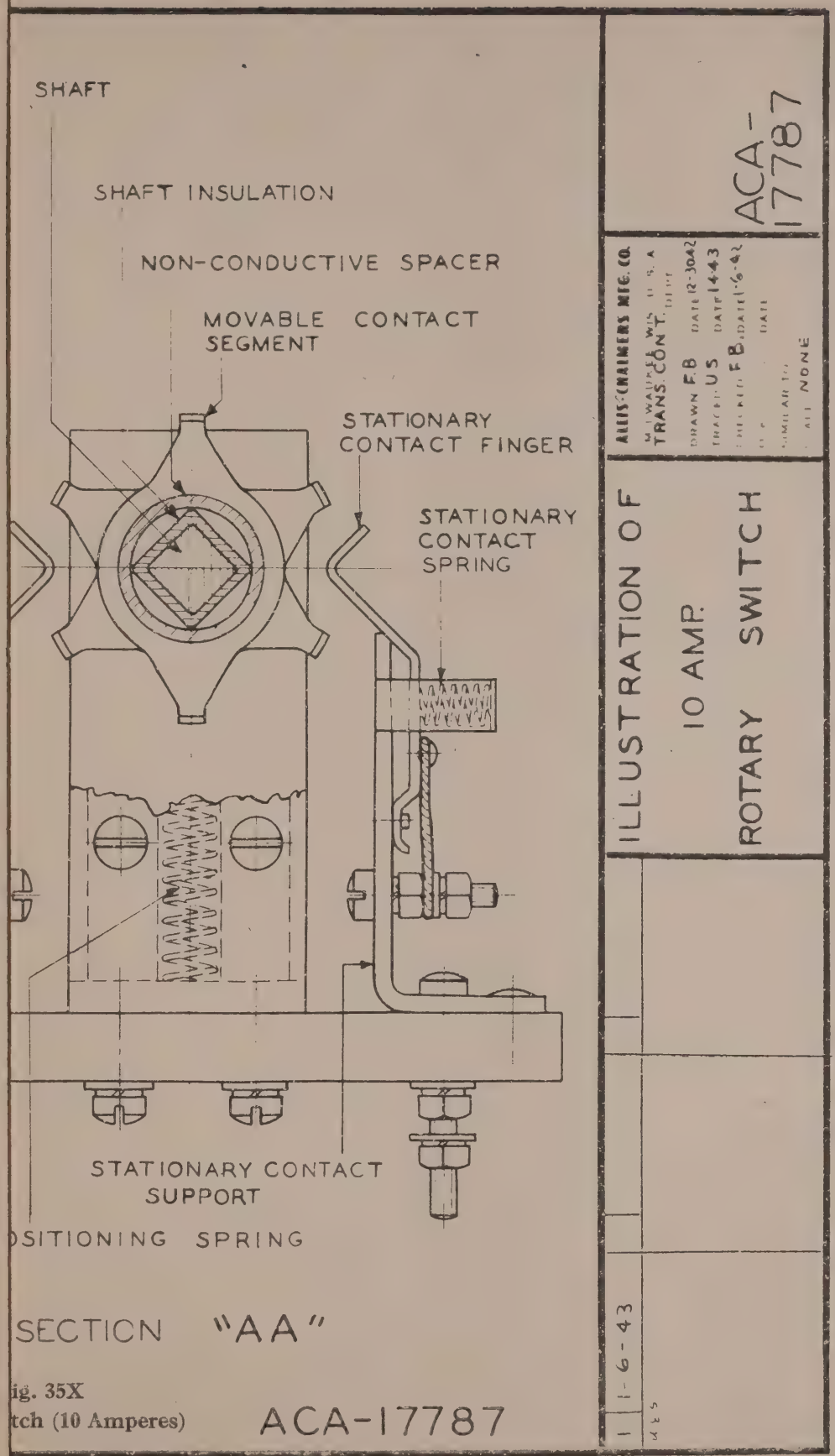


Fig. 34X
Push Button Switch (30 Amperes)

ACA-17788

1-7-42	ILLUSTRATION OF PUSH BUTTON SWITCH (30 AMPERES)	ALLIS-CHALMERS MFG. CO. MILWAUKEE, WIS. U.S.A. TRANS CONT. DEPT. DRAWN J.S. DATE 12-30-42 TRACED DH DATE 12-30-42 CHECKED DATE 1-7-42 O.K. DATE SIMILAR TO SCALE 8" = 5"	ACA-17788

Fig. 34X



ig. 35X
tch (10 Amperes)

Fig. 35X

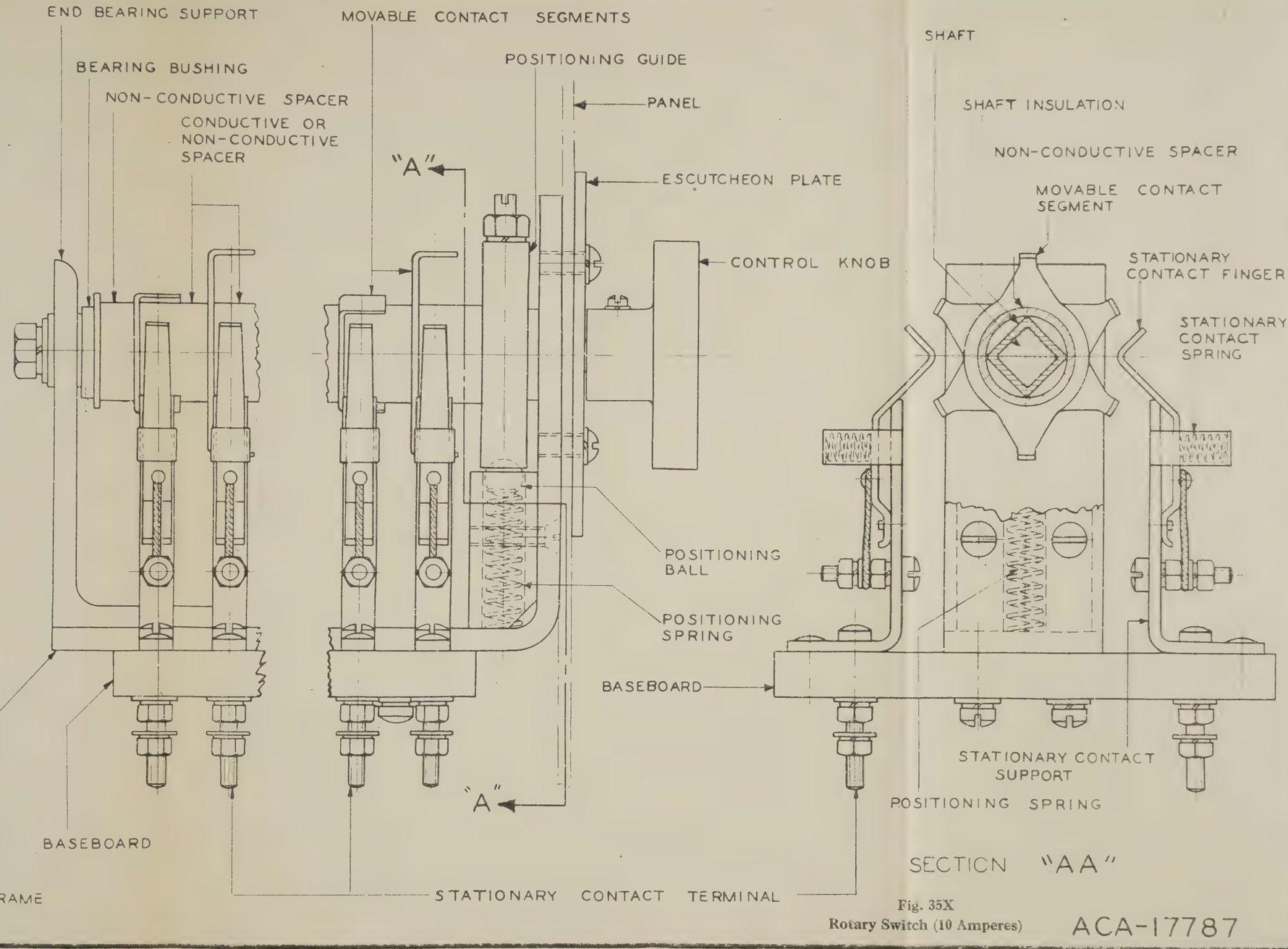
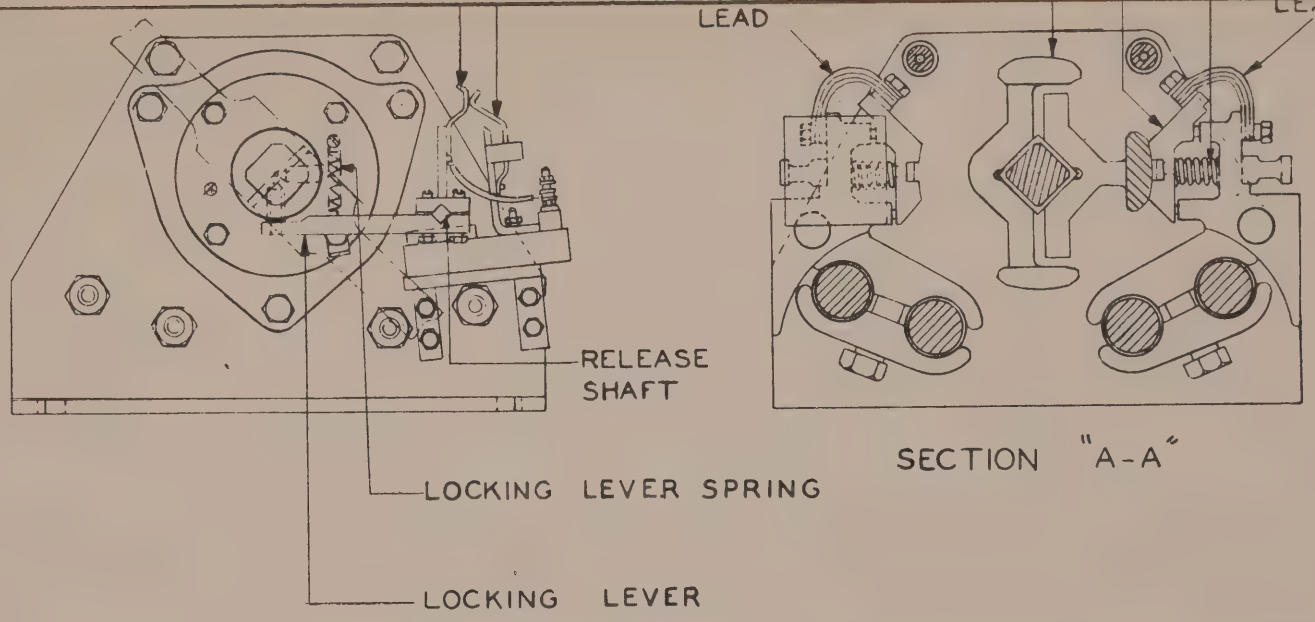


Fig. 35X
Rotary Switch (10 Amperes)

Fig. 35X



ACA-17761

1	11-2-42				

ILLUSTRATION OF GEN CUT-OUT SWITCH

ALLIS-CHALMERS MFG. CO.
MILWAUKEE, WIS., U. S. A.
TRANS CONT. DEPT.
DRAWN U.E.S. DATE 10-21-42
TRACED DAH DATE 10-22-42
CHECKED U.E.S. DATE 10-23-42
O. K. _____ DATE _____
SIMILAR TO EKK 157403
SCALE _____ -12"

ACA-17761

Fig. 36X

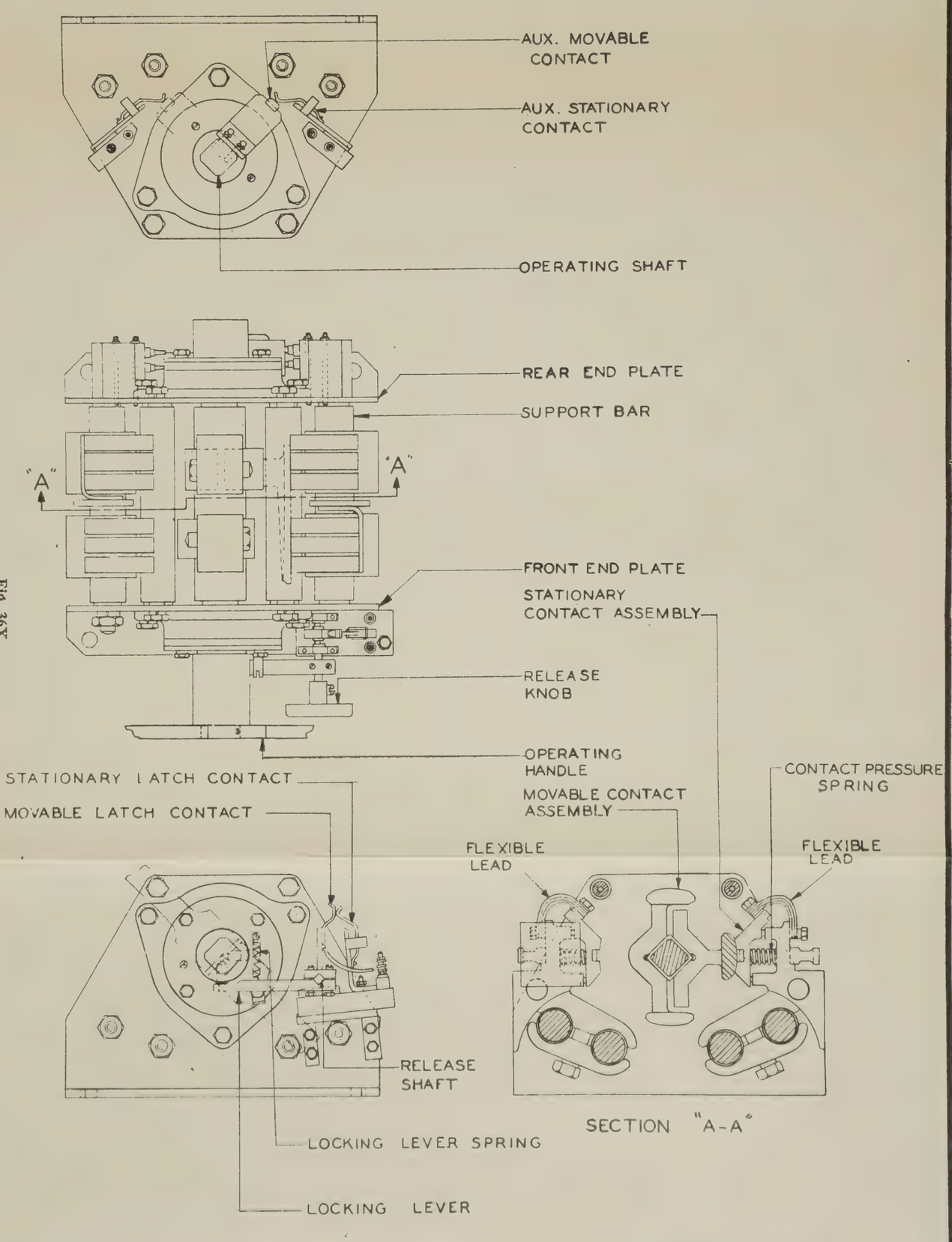


Fig. 36X
Generator Cut-Out Switch

ACA-17761

11-2-42				ILLUSTRATION OF GEN CUT-OUT SWITCH	ALLIS-CHALMERS MFG. CO. MILWAUKEE, WIS., U. S. A. TRANS CONT. DEPT. DRAWN U.E.S. DATE 10-21-42 TRACED U.A.H. DATE 10-22-42 CHECKED U.E.S. DATE 10-23-42 O. K. DATE SIMILAR TO NR 157403 SCALE 12"	ACA-17761

Fig. 36X

PROPULSION REDUCTION GEAR UNIT

General Design. This gear unit is of the single reduction type transmitting the power from two 765 h.p. electric motors, having a constant horsepower speed range from 700 to 875 r.p.m., to a single propeller shaft whose speed varies within this range from 160 to 200 r.p.m. The total power delivered by the electric motors is 1530 h.p., and that delivered in turn by the gear set to the propeller shaft is 1500 h.p.

Fig. 1Y shows clearly the arrangement and general features included in the design of this gear set.

Gear and Pinions. The assembly plan in Fig. 1Y shows the arrangement of the gear and pinions, the axes of all three being in the plane of the joint between the gear case and the main cover, as well as in the plane of the motor and propeller shaft axes. The pinions are alloy steel forgings of high tensile strength, heat treated to give adequate resistance to wear and fatigue.

The main gear, whose teeth are subjected to fewer repetitions of contact than those of the pinions, is a steel casting, heat treated for toughness and freedom from internal stress. Both gear and pinions have continuous double helical teeth generated on the Farrel-Sykes Generator, using cutters of 20 degree pressure angle and 30 degree helix angle.

The main shaft on which the gear is mounted is a medium carbon steel forging, heat treated.

Bearings. The pinion shaft, forged integrally with the pinion, is supported in standard Timken tapered bearings, Type NA (non-adjustable), which are free to float axially in their seats. There are two bearings per pinion and all four of them are identical.

The main shaft is carried in two standard Timken bearings. The aft bearing, Type NA, carries a radial load only, and is free to float axially in its seat. The forward bearing assembly carries a radial load from the gears and, in addition, the thrust from the propeller. It is made up of two single row bearings with a spacing sleeve between the two outer races. The two installed single row units and one spare single row unit have been specially selected for interchangeability.

The bearings are applied to their shafts with a light shrink fit obtained by heating in oil to a temperature not exceeding 250 degrees F. The thrust bearing is located axially by shaft shoulder and shaft nut, and the port pinion bearing aft by shaft shoulder and end plate. The starboard pinion bearing aft is located by shaft shoulder and tachometer generator drive gear. The remaining bearings are located by shaft shoulder and shrunk retaining sleeve.

The forward main thrust and radial bearing assembly is locked in its seat and constitutes the only absolutely fixed point in the gearing, all other parts of the gear train being free to adjust themselves to expansive movement.

Couplings. Mounted on and keyed to the after end of the main gear wheel shaft is the male half of a solid type coupling which registers with a mating half on the propeller shaft. A nut and washer secures this coupling half to the main gear wheel shaft.

For connecting the electric motors to the driving pinions, a solid type half coupling with female register is mounted on and keyed to the pinion shaft. It is machined to receive the flanged armature shaft.

Gear Case. The gear case is a semi-steel casting of rugged proportions rigidly supporting the bearings and the alignment of the gearing. Its joint with the main cover and with the various bearing caps lies in the common plane of the three shafts so that unshipping the cover and caps exposes the moving members and permits their removal vertically. Inside the case, under each pinion, an oil cooler basin, cast integrally, holds cooling coils attached to a cover. Removal of the cover takes the coils with it. The base flange of the case is provided with holes for bolting through chocks of the foundation structure, an ample proportion of the holes being designed for reaming to receive body-bound bolts for transferring the propeller thrust to the ship. Fig. 1Y indicates these holes in a sectional base plan. The wheel well extends below the supporting base to accommodate the main gear and provide oil storage.

Hung inside of the bottom case and bolted to Supporting flanges in this case is a sweep pan fabricated of sheet steel.

For a clear picture showing details of construction see Fig. 1Y.

Lubricating System

General Description. Oiling of gears and bearing is accomplished through a system of splash lubrication. Oil to the amount of 105 gallons is stored in the lower portion of the gear case, which constitutes a reservoir. Referring to Fig. 1Y, the main gear dips below the reservoir level but is surrounded below its center line by an oil sweep pan which receives oil from the reservoir through small ports in the bottom of the pan. At rest the oil inside the pan stands at reservoir level. In motion the gear throws the oil from within the pan, upward to the mesh with one of the pinions. A small fraction of this oil goes through the mesh and the remainder, for the most part, falls to the cooling basin under the pinion. Equalizer pipes connect this basin with the one under the other pinion. Circulation through the pipes raises the level of oil in this basin until the pinion dips into it and splashes oil into its mesh with the gear. In reverse motion the two meshes reverse this method of lubrication.

Due to the retarded inflow through the restricted ports in the bottom of the sweep pan, the oil level within this pan is lower in motion than the reservoir level and excessive oil churning by the gear is eliminated. The level of oil in the cooling basin is controlled by the height of the oil sweep pan which forms the upper half of the inner side of the basin. The height of this pan has been made so as to limit the level to a point where excessive churning will not result.

Splash striking the sides of the main cover drains to collector channels disposed along the sides of the gear case at its joint with the cover. These channels, plainly visible in the sectional view, Fig. 1Y, lead oil to the various bearings into which it gains entrance by means of oil retaining rings shown in Fig. 1Y. Return to the reservoir is by means of holes drilled through the bearing supports. Entrance to the return channels is at such a level that the bearing rollers always dip in an oil bath.

Oil Cooler. The cooler provided is a tube type cooler with the water flowing through the tubes and the oil circulating freely over the outside.

Operation and Inspection. To insure satisfactory performance of the gears, the lubricating system must be in complete working order. Lubrication is assured if the oil level is up to the full mark indicated on the bayonet gauge. A high grade oil of 1000 S.S.U. at 100° F. is recommended.

It is very important that the condition of the lubricating oil be constantly observed and checked for entrained water and foreign solid matter. The presence of dirt or water is very detrimental to the gears and bearings. Immediate steps to remedy such condition cannot be too strongly emphasized.

Routine Inspection During Operation. While the gear is in operation the bearing temperatures should be estimated periodically by hand contact. Should the heat of all bearings and the case become excessive, the cooling water supply should be investigated. If the water supply proves adequate, the cleanliness of the oil cooler and the remote possibility of obstructions in the equalizer pipes should be investigated. Should the temperature of only one bearing become excessive, the bearing baffle should be removed and an examination made.

Maintenance

Gear Tooth Surfaces. There should never arise the need for service work on the tooth surfaces provided proper lubrication and correct alignment of gear and pinions are maintained. The tooth contours and surfaces are designed to absorb the reversal stresses of the propelling unit when operating within its specified capacity. An injury to a tooth surface would show up as pitting or as a foreign particle of imbedded material causing successive indentations in the teeth it engages. Careful stoning to remove high spots and restore the tooth contours is the only procedure advisable, using caution to prevent entrance of metal or abrasive particles into the oil.

Bearings. If, when the shafts are jacked up from their bearing seats, inspection discloses noticeable end play of rollers between cones and cups or if, when in service, excessive noise is localized at a bearing, replacement is indicated. In practically every case impending trouble would be announced by noisy operation. It is essential that replacement consists of a complete bearing unit-cone, cup, and rollers.

To provide a hold for puller bolts in drawing an old bearing, half round notches have been milled in the shafts at the inner sides of the bearings. If heat is necessary for removal, the shaft and especially the gear teeth should be shielded from contact with the flame.

To mount the new bearing, it should be expanded by heating in oil not over 250° F. While it is cooling on the shaft, it should be tapped with a block of

hard wood to keep it up against the shaft shoulder, which condition should be checked after the bearing has gripped the shaft. In the case of forward pinion bearings and after gear bearing, the collars should be shrunk on in the same manner.

Oil Cooler. The oil cooler should be cleaned whenever objectionable increase in pressure drop through the unit or decrease in cooling efficiency is observed.

Before removing tube bundle from case, drain water line and also the oil cooler pockets by removing 1½" pipe cap on end of equalizing pipe shown in Fig. 1Y.

Remove the tube bundle by taking off the nuts securing it to the case. Place in a container with enough solvent to cover it and permit agitation. Forced circulation of the cleaner through the inside of the tube may be facilitated by means of an ordinary grease gun or rubber suction cup. Agitation of the tube bundle will clear it of any insulative dirt or sludge which may have accumulated on the cooling surfaces.

Look through the tube group in five directions; through the avenues between the tubes to determine if any foreign matter still adheres to the tubes. If necessary, run a cloth-covered metal strip along the avenues between the tubes to loosen any adherent matter. In some cases the dirt may be of an asphaltic nature. If any dirt still adheres to the tubes, place the tube bundle in a mild alkali solution, such as: soda ash or tri-sodium phosphate, .04 lb.; water, one gallon; sulfonated fatty alcohol, .004 lb.; boil slowly with steam jet, keeping steam from direct contact with adherent dirt. Rinse with hot water and dry. Blow high pressure air or steam. through the tube to remove any lodged particles. Blow high pressure air over the tube bundle to dry.

Installation

The gear set is provided with a strong machined base containing an adequate number of bolt holes to allow for firm and rigid connection to the ship's foundation.

Great care must be exercised to install these gears so that full tooth contact and good alignment of all connecting shafts are obtained.

If tooth contact—after the ship has been put into service—has changed, it is advisable to recheck the alignment of the shafting and take the necessary measures to restore the original setting of the gear unit.

Repair and Replacement Orders

The handling of repair and replacement orders at the factory will be facilitated if the following directions are carefully observed:

1. Give the type and size of the unit as stamped on the name plate.
2. Give order number.
3. Give the name of the ship.
4. Designate the parts required by the part numbers appearing in the instruction book or reference drawings.
5. Give the number of the reference drawing from which each part number is obtained.
6. Specify plainly the number of parts desired.
7. Give complete shipping instructions.

In returning the parts to the factory be sure that each part is tagged with all information necessary for complete identification.

SPARE PARTS

Reduction Gear

Item No.	*No. per Vessel*	*Description*	*Mfg.'s Identification*
		Box No. 1 Containing Following Spare Parts & Wrenches	
1	1	Wrench (For Main Shaft Nuts)	B2-7921-4
2	1	Wrench Bar	
3	2	Timken Roller Bearing	NA74525-74851D
4	2	Studs (11 Threads)	$\frac{5}{8}$ x $2\frac{3}{8}$"
5	2	Studs (11 Threads)	$\frac{5}{8}$ x $2\frac{1}{2}$"
6	1	Studs (8 Threads)	1 x $7\frac{1}{2}$"
7	1	Studs (7 Threads)	$1\frac{1}{4}$ x $5\frac{1}{4}$"
8	1	Studs (7 Threads)	$1\frac{1}{4}$ x $9\frac{1}{2}$"
9	1	Studs (7 Threads)	$1\frac{1}{4}$ x $10\frac{1}{2}$"
10	3	Hexagon Head Tap Bolt (13NC3)	$\frac{1}{2}$ x $1\frac{1}{2}$"
11	2	Allen Cap Screw	$\frac{5}{8}$ x $1\frac{1}{4}$"
12	6	A.S. Hexagon Head Bolt (2"—7 Thread)	$1\frac{1}{4}$ x $4\frac{1}{2}$"
13	3	Hexagon Head Tap Bolt (10NC3)	$\frac{3}{4}$ x 2"
13A	2	Hexagon Head Tap Bolt (10NC3)	$\frac{3}{4}$ x $1\frac{1}{2}$"
14	2	Semi-Finished Hexagon Nuts (11NC3)	$\frac{5}{8}$"
15	2	Unshako Hexagon Nut (11 Thread)	$\frac{5}{8}$"
16	1	Unshako Hexagon Nut (8 Thread)	1"
17	9	Unshako Nut (7 Thread)	$1\frac{1}{4}$"
		Box No. 2 Containing Spare Bearing	
1	1	Timken Roller Bearing	NA101103-101601
		Box No. 3 Containing Spare Bearing	
1	1	Timken Double Row Bearing (Complete with Spacer)	EE390095-390200

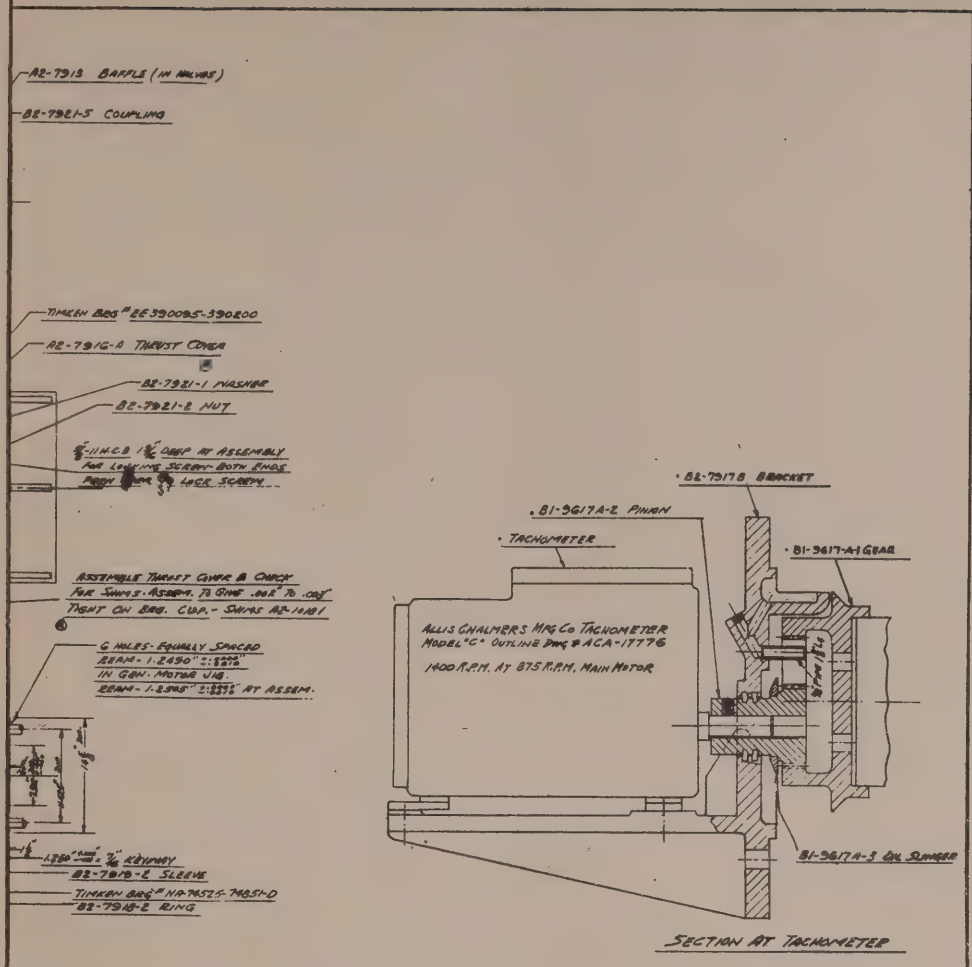

AE-7913 BAFFLE (IN HALVES)
BE-7921-5 COUPLING
TIMKEN BRG NO EE390085-390200
AE-7916-A THRUST COVER
BE-7921-1 WASHER
BE-7921-2 NUT
LOCK SCREW
ASSEMBLE THRUST COVER & CHECK FOR SHIMS - ASSEMBL. TO GIVE .002" TO .004" TIGHT ON BRG. CUP. - SHIMS AE-10181
6 HOLES - EQUALLY SPACED
BEAM - 1.2490" 2:3295"
IN GEN. MOTOR J/B
BEAM - 1.2495" 2:3295" AT ASSEM.
BE-7918-2 SLEEVE
TIMKEN BRG NO NA 74525-74851-D
BE-7918-2 RING
BAG CAP
PIPE TAP-WATER INLET
COOLING WATER INLET & OUTLET SIMILAR AT OTHER END EXCEPT OPPOSITE HAND
BE-7917B BRACKET
BI-3617A-2 PINION
TACHOMETER
BI-3617-A1 GEAR
ALLIS CHALMERS MFG Co TACHOMETER
MODEL "C" OUTLINE DWG # ACA-17776
1400 R.P.M. AT 875 R.P.M. MAIN MOTOR
BI-3617A-3 GR. SLEEVE
SECTION AT TACHOMETER

Fig. 1Y
Reduction Gear Outline

DATA

GEARS 40/175 T. 3 D.P. 16" FACE
30° HELIX ANGLE 20° PRESSURE ANGLE
TWO 750 HP MOTORS (1500 HP TOTAL) @ 875 R.P.M.
FULL SPEED - ALSO FULL POWER @ 80% SPEED (700 R.P.M.)
RATIO 4.375/1 PROPELLER THRUST 40,000#
WGT - 16,700#

REVISED	FARREL-BIRMINGHAM CO., INC.
	ANSONIA, CONN. DERBY, CONN. BUFFALO, N.Y.
	MACH. REDUCTION GEAR, TWO PINION TYPE
	FOR GEN. MOTORS CORP.
	ORDER U-1214 SU-1570
	DRAWN CT G.
	CHECK'D MEP. D2-10161
	SCALE
	DATE 8-12-43

Fig. 1Y

SPARE PARTS

Reduction Gear

Item No.	*No. per Vessel*	*Description*	*Mfg.'s Identification*
		Box No. 1 Containing Following Spare Parts & Wrenches	
1	1	Wrench (For Main Shaft Nuts)	B2-7921-4
2	1	Wrench Bar	
3	2	Timken Roller Bearing	NA74525-74851D
4	2	Studs (11 Threads)	5/8 x 2 3/8"
5	2	Studs (11 Threads)	5/8 x 2 1/2"
6	1	Studs (8 Threads)	1 x 7 1/2"
7	1	Studs (7 Threads)	1 1/4 x 5 1/4"
8	1	Studs (7 Threads)	1 1/4 x 9 1/2"
9	1	Studs (7 Threads)	1 1/4 x 10 1/2"
10	3	Hexagon Head Tap Bolt (13NC3)	1/2 x 1 1/2"
11	2	Allen Cap Screw	5/8 x 1 1/4"
12	6	A.S. Hexagon Head Bolt (2"—7 Thread)	1 1/4 x 4 1/2"
13	3	Hexagon Head Tap Bolt (10NC3)	3/4 x 2"
13A	2	Hexagon Head Tap Bolt (10NC3)	3/4 x 1 1/2"
14	2	Semi-Finished Hexagon Nuts (11NC3)	5/8"
15	2	Unshako Hexagon Nut (11 Thread)	5/8"
16	1	Unshako Hexagon Nut (8 Thread)	1"
17	9	Unshako Nut (7 Thread)	1 1/4"
		Box No. 2 Containing Spare Bearing	
1	1	Timken Roller Bearing	NA101103-101601
		Box No. 3 Containing Spare Bearing	
1	1	Timken Double Row Bearing (Complete with Spacer)	EE390095-390200

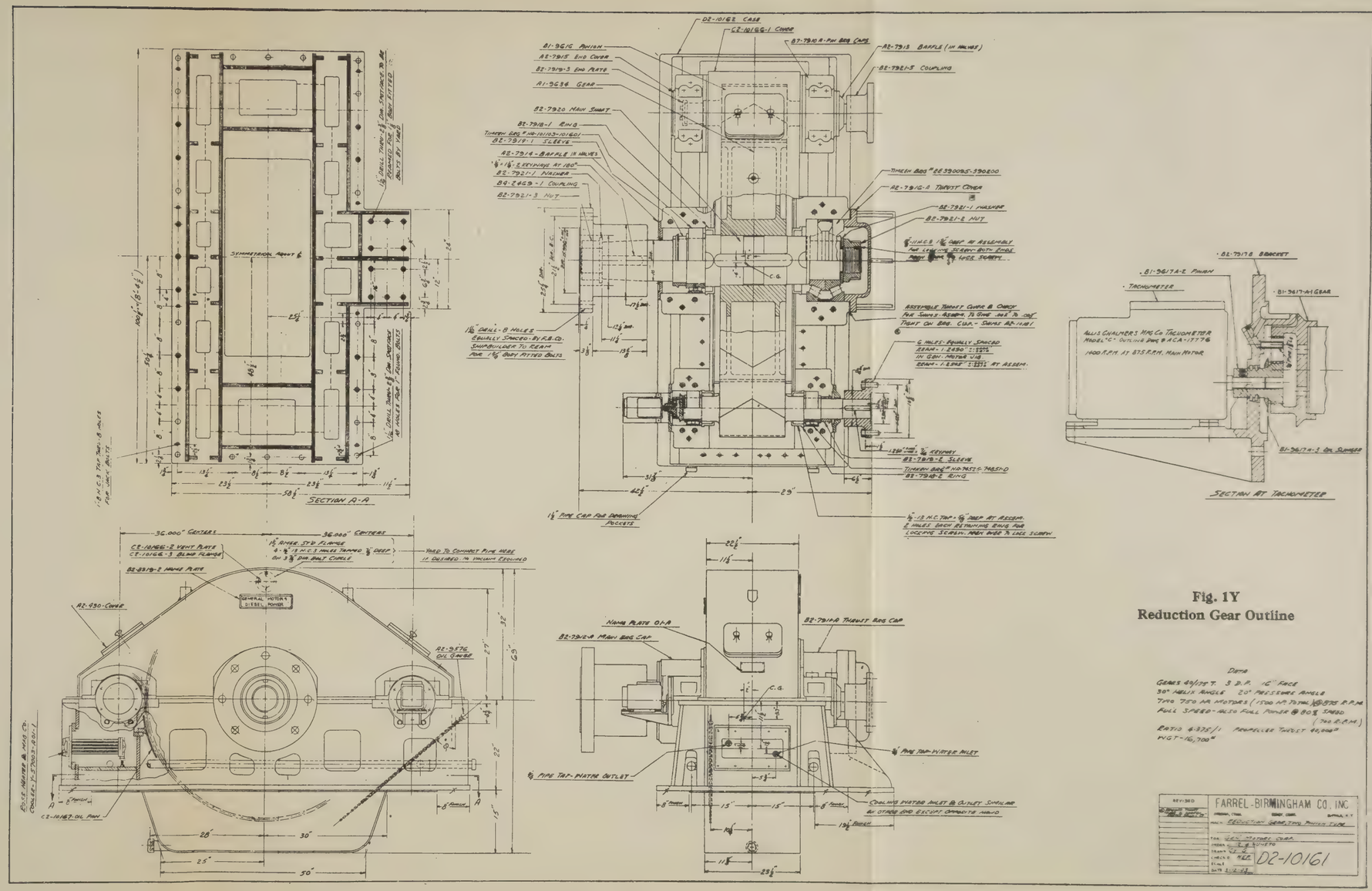

SECTION A-A
SECTION AT TACHOMETER
ALLIS CHALMERS MFG Co TACHOMETER MODEL "C" OUTLINE DWG # ACA-17776 1400 R.P.M. AT 875 R.P.M. MAIN MOTOR
FARREL-BIRMINGHAM CO. INC.
REDUCTION GEAR, TWO PINION TYPE
DRAWN C.E.B.
TRACED W.L.
CHECKED W.L.
DATE 1-2-43
D2-10161

Fig. 1Y
Reduction Gear Outline

Data

GEARS 49/17 T. 3 D.P. 10" FACE
30° HELIX ANGLE 20° PRESSURE ANGLE
TWO 750 H.P. MOTORS (1500 H.P. TOTAL @ 875 R.P.M. FULL SPEED - ALSO FULL POWER @ 80% SPEED (700 R.P.M.)
RATIO 4.375/1 PROPELLER THRUST 40,000#
WGT - 16,700#

Fig. 1Y

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